THE TRUE BOOK ABOUT INVENTIONS

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INVENTIONS

by

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Chapter One

IDEAS IN BLACK AND WHITE

THE book which you hold in your hands is printed. You will say: of course it's printed; otherwise it wouldn't be a book.

But you are wrong. Books have been printed only for the last five hundred years—a very short period in the history of mankind. Before that, books were handwritten, laboriously and painstakingly, by Egyptian scribes and Roman slaves and medieval monks.

There was once a library of written books, 400,000 volumes of them, in Alexandria in Egypt. It contained all the knowledge and wisdom, the literature and folklore of the ancient world. It was burnt to ashes during the upheavals which followed the fall of the Roman Empire. What it contained was lost for ever; for only a few of those 400,000 books existed in duplicates. The flames that destroyed the library of Alexandria robbed us of an immense wealth of genius, learning, and beauty.

It can't happen again. For we have learnt the art of printing, and no book worth reading exists only in one copy. It has been said that Man's greatest invention is the wheel; but perhaps the invention of printing is even greater. We do not know very much about the circumstances of that invention; but the little we know shows that it had quite a dramatic history.

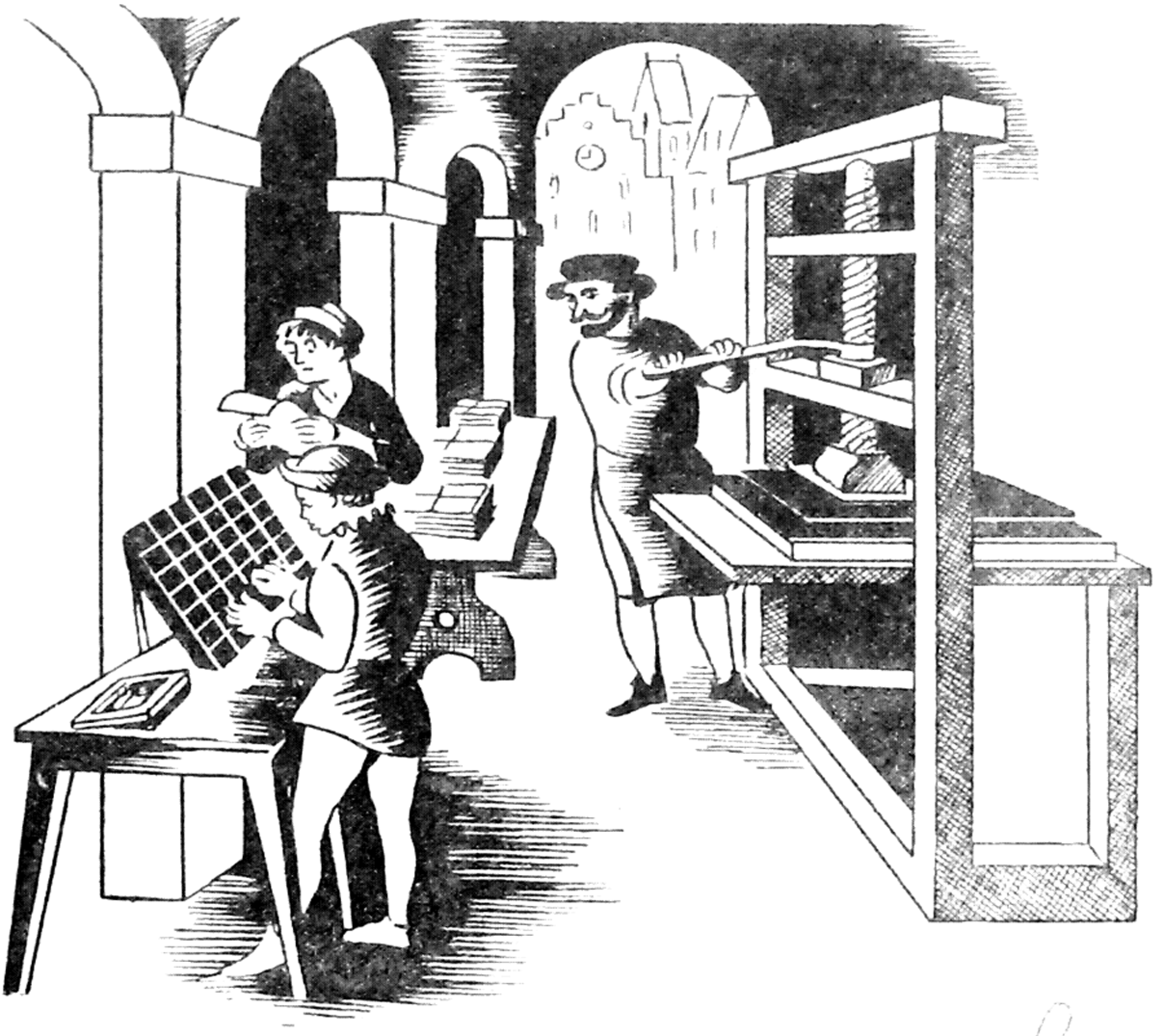
Who Invented the Movable Type?

This book will tell you that a number of inventions were made by a number of people at the same time, and that sometimes it is very difficult to say who was first. At certain periods in history, various ideas were "in the air"; for some reason there was a demand for this or that machine or device, and usually several people tried to solve the problem independently of each other, in different countries. Inventions must have a "market" to be successful; many inventions were made *before* they were wanted, and the men who made them and who had spent their money and energy on them remained unknown and unsuccessful. The secret of becoming a successful inventor is to fulfil a popular demand. But when that demand arises there are sometimes various inventors who set their brains and hands to work, trying to solve that particular problem.

It happened five hundred years ago—when the Middle Ages drew to an end. In that century, the fifteenth, many important things happened. Martin Luther reformed the Christian religion. The Turks conquered Constantinople. Columbus discovered America. A new wind blew across Europe, awakening the masses of the people, making them aware that they were thinking human beings, and exciting their eagerness to be informed, to learn—to read.

In the Dutch town of Haarlem there are two monuments celebrating the invention of printing with movable types by one Laurens Coster. The little Italian town of Feltre has another monument in honour of a doctor who lived there and who is supposed to have made the same invention. In Strasbourg and in Prague are also memorials making the same claim on behalf of their citizens. In each case, the invention is claimed to have been made in the same period—the first half of the fifteenth century.

History, however, has not accepted these claims. It has decided that Johann Gensfleisch zum Gutenberg, who was born at Mainz in Germany a few years before 1400, was the true inventor of printing with movable letters.



Early printing: Gutenberg's workshop

Gutenberg's Tragic Fate

Gensfleisch was the name of a rich family of burghers who lived in a quarter of Mainz called the Gutenberg, and as the German word Gensfleisch means "flesh of the goose" young Johann decided to call himself Gutenberg because it was a better-sounding name. At that time, the city authorities introduced stringent new taxes, and Gutenberg, who thought that his family and the other patricians were unfairly treated, left Mainz in protest and settled in Strasbourg, on the other side of the Rhine.

There, Gutenberg seems to have occupied himself with the printing of "block-books", a system which preceded the printing with movable type in Europe as well as in China: single pictures were cut on wood-blocks, often with some text explaining them, inked, and the picture transferred to a sheet of paper by rubbing or pressing. A number of books were put together in this way. It was "printing" all right, but of a very primitive, tiresome, and clumsy kind.

This was what Gutenberg did in Strasbourg after trying his hand at cutting gems and polishing mirrors by some new method. He appears to have invented a special printing-press for woodcuts, for there are some documents relating to a complicated lawsuit in which he was involved—the case revolving around some secret kind of press, which had disappeared. Was it then that he first thought of using individual, movable letters to compose words, pages, and whole books?

He returned to Mainz around 1444 after having lived in Strasbourg for ten years. He was now a man of fifty, and his great idea had probably developed quite clearly in his mind: to make moulds, one for each letter of the alphabet, from which to cast movable little metal types, exactly alike in length so that they could be put together to form lines, and the lines assembled to form pages. A man with such an idea must have been a kind of rebel; for his system would enable printers to produce books cheaply, thus making the treasure-trove of knowledge available to everybody—instead of keeping it jealously from "the people". The wealthy and the nobles firmly believed that too much knowledge would put ideas into people's heads, and that the Common Man's obedience towards his "betters", the overlords and princes and church dignitaries, might cease once he had learned to read and think. Gutenberg may have believed that the world would be a better place if the Dark Age, the age of ignorance, came to an end; at any rate, his invention provided the people with a powerful weapon of the mind. It marked the beginning of Modern Times.

However, then—as now—experimenting cost money, and Gutenberg had spent his own in Strasbourg. So he interested a wealthy lawyer and patrician of Mainz, Johann Fust, in his project, and Fust advanced him a loan of 800 florins, a substantial sum; and they made a contract which gave Fust equal rights in the invention and contained a few cleverly contrived clauses, whose meaning Gutenberg did not grasp fully at first. He was soon to find out.

Gutenberg designed beautiful letters, from which a number of alphabet sets were cast. Big presses, with six-foot bars to operate them, were set up. Slowly, with much trial and error, the inventor proceeded from experimenting to actual printing. He chose the reproduction of an old German religious poem as his first job. The system worked!

Then, in 1455, the first printer's shop turned out its masterpiece—the entire Bible in Latin, 1,282 pages of 42 lines each: a gigantic undertaking for such a small, and still largely experimental, enterprise; it must have taken many years to complete, and strained the Gutenberg-Fust partnership beyond breaking-point. For when this famous and magnificent book was at last completed, when the final sheet had been printed and bound, Fust demanded repayment of his loan.

Gutenberg, engrossed in his work, had not expected such a cruel blow, and could not raise the money. Fust, the clever lawyer, had been waiting for years for this chance. There was nothing, absolutely nothing, Gutenberg could do. He was forced to give up his house, his workshop, and leave behind every book he had printed. At once, Fust brought in his son-in-law, and, with his help and that of the assistants Gutenberg had trained, the world's first printing works soon became exceedingly prosperous.

We know little about the rest of Gutenberg's life, except that the charitable Archbishop of Nassau made him an honorary member of his household. That was in 1465, ten years after the publication of his Bible, and only two years before his death. At least he spent his last two years of life in peace and quiet.

How Printing Came to England

William Caxton was born in Kent. He wanted to be a merchant, and went to Bruges in Belgium where he learnt his trade as an apprentice to a silk mercer. Then he set up his own business and was so successful that he was appointed governor of the famous company of Merchant Adventurers. In this capacity he negotiated commercial treaties between Brabant and the Dukes of Burgundy. In 1469, when he was in his late forties, Duchess Margaret, wife of Charles the Bold of Burgundy, engaged him as her commercial adviser.

Two years later, however, we find him in Cologne, where he became for the first time interested in the art of printing. He decided to learn it. Then he returned to Bruges and printed the first book in the English language, his own translation from the French of a collection of stories from Homer's *Iliad*, in 1474. He decided to set up his printing-shop in Westminster—the first to be established in England.

He never regretted abandoning his career as a merchant and courtier relatively late in life to take up an entirely new trade. Printing fascinated him; and when he died in

1491, at the age of 70, he had the satisfaction of having brought many masterpieces of literature within the reach of his countrymen. Perhaps the greatest service that he rendered to his country was that he standardized the written English language at a time when spelling was a confused business and grammar at anybody's mercy.

For more than three hundred years, the technique of printing remained the same. Letter type was set by hand, and prints made with hand presses. A new product came off the printing presses in the seventeenth century—the newspaper. At first it was a leisurely affair; papers were published when there was news, and no one was in a hurry to read about the very latest happenings. But the development of trade and shipping and the growth of Britain's far-flung Empire made it necessary to supply regular and reliable up-to-date information. It was this need which prompted a former underwriter at Lloyd's, Mr. John Walter, to found a newspaper which was first called *The Daily Universal Register* and later, from 1788, *The Times*.

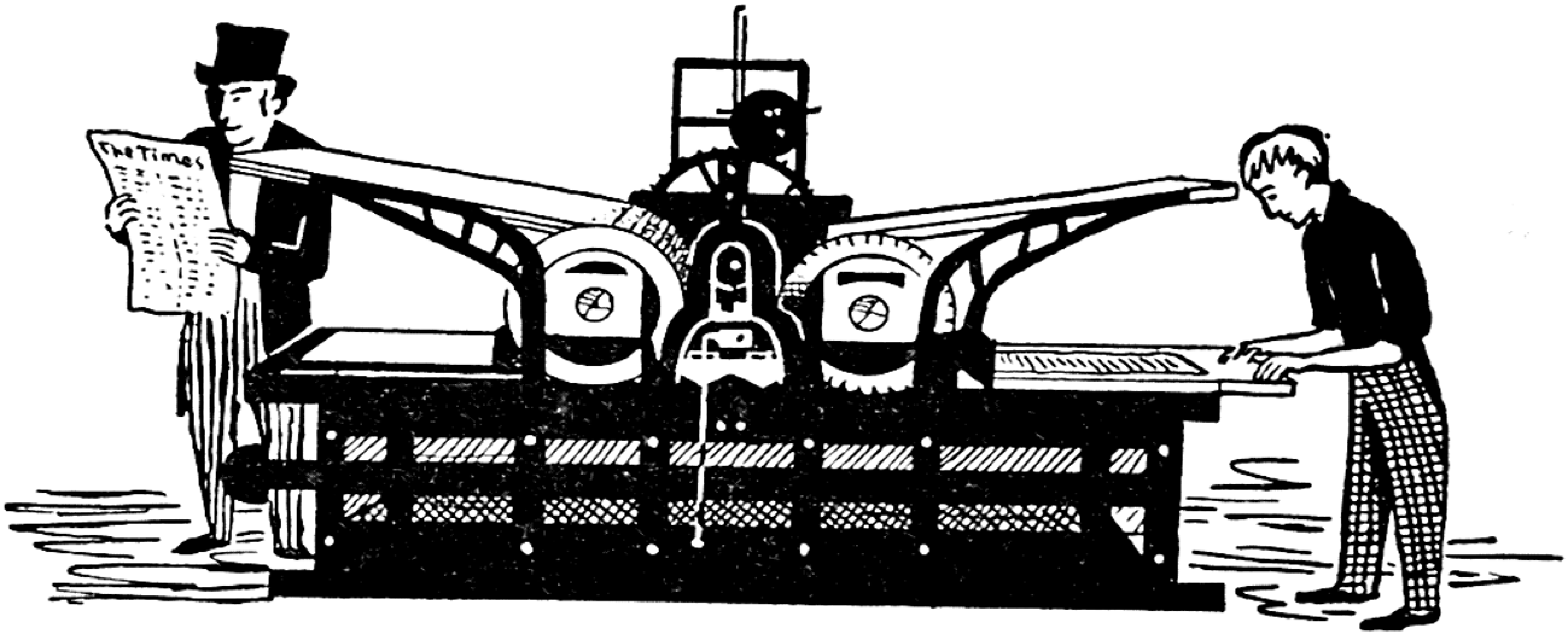
It was *The Times* which introduced a whole series of inventions connected with printing throughout the nineteenth century. One day in 1812, John Walter II, the son of the founder, was asked by a friend to come to a workshop in Whitecross Street where he would see the greatest advance in the art of printing since the days of Gutenberg. What he saw was a demonstration of the first practical mechanical press, worked by steam power.

The inventor of that machine was a printer from Germany, Friedrich König, who had come to England because the patent laws in this country protected an inventor much better than in Germany—a country then divided into two dozen principalities, so that a patent taken out in one of them was without value in the others.

König found a financial backer for his idea, a Mr. Bensley, and a skilled mechanic, another German, by the name of Friedrich Bauer.

Bensley helped König and Bauer to conclude a contract with John Walter for the delivery of two double machines for *The Times* and the *Evening Mail*, and put up the necessary money. The completion of these large machines took two years.

König's idea was simple. So far, every single sheet to be covered with print had to be put by hand on top of the type in the press, which had been inked by hand, and the press bar then swung round or pushed down, also, of course, by hand. Even the most skilled printers were unable to produce more than 300 newspaper copies in an hour. Now that the steam engine was available as a source of power, König let the whole process be done mechanically: the "forme" with the type moved forward and backward under the inking cylinder, receiving a fresh sheet of paper which was put into the right position mechanically and pressed against the forme by another cylinder. The printed sheet was then delivered into the hands of a printer at the other end of the machine, while the forme moved back again to receive another coat of ink



König's mechanical press (1814)

and pick up another sheet of paper. Thus, 1,000 to 1,200 copies could be printed in an hour, with much less labour.

The *Times* printers had heard of the new machines and feared for their jobs. When the machines were loaded on to a van to be transported to the *Times* building, they barred the way and threatened the coachman.

Walter installed the machines secretly in another building. One night in November, 1814, he told his workers to wait with the production of the morning paper as he was still expecting some important news items from the Continent. The printers did not see anything suspicious in that. But a few hours later, Walter entered their room with a bunch of copies of *The Times*—printed in secret with the new mechanical press!

What appeared at first to endanger the bread and butter of the printers soon turned out to be a great boon for the whole printing trade. Mechanical production of newspapers, and later of books and magazines, made reading so much cheaper, and the demand for it grew by leaps and bounds. Later in the nineteenth century, John Walter III, son of No. II, introduced the rotary press, with continuous paper supply from huge drums; it uses cylinders with round "stereotype" plates instead of flat type formes, made by making an impression of the set-up type in damp papier-mâché and then bending it into a round shape while pouring molten metal into it. To-day, rotary printing presses are producing the millions of copies which the readers of our great daily papers demand.

After paying their debt to Bensley, König and Bauer had just enough money left to return to the Continent. In Bavaria they established a factory for mechanical printing-machines in a former monastery, and trained peasant lads as mechanics. In the end, by persevering, they built up a flourishing business, which is still in existence to this day.

Another young German who had settled in America, Ottmar Mergenthaler, invented a machine which could set type—a job which had been done by hand for over 400 years. In 1887, the machine—the first of its kind—was set up in the New York *Tribune*. It was—and still is—called "linotype" because it assembles the type in a line from matrices brought into position by pressing keys on a typewriter-like keyboard; the line then being cast in lead automatically. It was this machine which started the "Modern Age" of printing.

Chapter Two

STEAM AND STEEL

It is strange to think that the latest and most modern of kitchen utensils—the pressure cooker—is, in fact, no less than 275 years old.

The story of the pressure cooker is really the story of the steam-engine. It goes back to a day in 1680 when Denis Papin, a young French scientist, entered the kitchen of the fine house in Pall Mall, London, where he was living as the guest and pupil of Professor Robert Boyle, the great scientist.

Monsieur Papin had been allowed to do some cooking for the family at his own request. He wanted to try out an invention of his, which he had developed in Boyle's laboratory. It was a new kind of cooking-pot, much taller than the usual saucepans, and looking more like a machine than a piece of hardware. It was an iron boiler, the lid of which was fastened with clamps, with a little valve for letting off steam.

A Scientific Dinner

"I took beef bones that had never been boiled, but kept dry a long time," Papin described his first experiment with this machine, "and of the hardest part of the leg; these being put into a little glass pot, with water, and inserted in the engine."

The "engine" was then put on the fire, and Papin watched it with some excitement. He was a handsome fellow, thirty-three years old, and seemed to possess great talent for scientific research. He was the son of a French Court official and a Huguenot, a Protestant. Like so many scientists and inventors before him he wanted to use steam power in an engine so that it would relieve Man of some of his labour. But the first practical result of his experiments was the "bone digester", as he called his novel cooking-pot.

Denis Papin shows his "pressure cooker"
to Robert Boyle (1680)

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Papin's idea was that when the boiling water or juice is confined in a pot so that the steam cannot escape, the pressure becomes so great that the steam is heated far beyond the boiling-point—we call it super-heated steam to-day. Thus the bones in the pot are not only boiled but steamed, and the toughest meat softened in a short time.

Papin also designed an automatic safety-valve—an invention for which alone he would have been famed in technical history, and which has remained essentially the same to this day. It is forced open when the steam pressure becomes too strong.

Professor Boyle took the young inventor to the Royal Society, where he introduced his bone digester to the learned gentlemen—again in the form of a meal.

Everybody congratulated the inventor, but he said, "I consider this machine only the first step towards a steam-power engine which I shall invent one day."

The scientists shook their heads, and some warned Papin gravely that so far all efforts to build such a machine had been in vain. True, the idea was an old one; Hero, a Greek philosopher, was the first who carried it out: he built a hollow metal ball with two jets, and suspended it over a fire so that it could rotate between two pivots. When water was put inside the ball and heated by the fire, the steam was forced out from the jets, and rotated the ball by pushing against the surrounding air.

A Huguenot at the Landgrave's Court

Denis Papin could have stayed on in England, where his bone digester—later called "Papin's Pot"—had made his name well-known. But just then the French king revoked the Edict of Nantes, that solemn guarantee assuring the Huguenots of religious freedom. So Papin had become an exile.

At this turning-point of his life, a German Protestant prince, the Landgrave of Hesse, offered him a chair at the University of Marburg. He accepted, hoping that under the protection of an enlightened prince he would be able to work out his great idea—an engine that could turn the wheels of a paddle-ship.

But the Landgrave was not in the least interested in that idea: and Papin had to go begging for every screwdriver and every bolt. He could build only a small model of what he called an "atmospheric machine", but he described it in detail in a pamphlet published in 1690. It was, in fact, the first practical steam-engine, with only one major fault: that it was a century ahead of its time.

It was Papin's ingenious idea, later taken up by all those who designed steam-engines, to use the cylinder and piston of an ordinary suction pump: the piston is forced up by the action of the expanding steam, and down by its sudden cooling which creates a vacuum underneath the piston so that the atmospheric pressure pushes it down. The cooling was to be done by a jet of cold water in Papin's engine.

The disappointed inventor decided to leave Germany and return to England. He built a large boat with paddle-wheels to be turned by hand-cranks (a system which he had seen in England), but he designed it so that a steam-engine could be built into it later on. As an eloquent protest against the lack of support for his ideas in Hesse, Papin intended to crank the vessel, with himself, his wife, and his numerous children on board, all the way from Cassel to London on the Fulda, the Weser, along the Dutch coast, and across the Channel to London.

They did not get very far. At the next town, Münden, the watermen's guild held them up, there was an argument which developed into a tussle, and the watermen demolished the boat with pick-axes.

Penniless, he arrived back in London, trying in vain to find employment. Erstwhile friends had died or else forgotten him, and the desperate struggle for a bare livelihood went on for five years.

We do not know how Papin's tragic story ended, nor where he was buried. During his lifetime, however, an English inventor had taken up his ideas. Captain Thomas Savery received a patent for his machine for pumping water out of mines—a most important task—and built several of these engines at considerable profit to himself.

Then there was Thomas Newcomen, a blacksmith, ironmonger, and Baptist preacher of Dartmouth. Watching one of Savery's water-lifting machines, he thought he could improve upon it. And he did so; Newcomen machines were much in use throughout the greater part of the eighteenth century in English mines. But these machines were not yet efficient enough to drive ships or relieve Man of his most tiring jobs; they made only 12 or 15 strokes a minute. The steam-engine had to wait until a technical genius took it into his hands to make it a tool that was to reshape the whole pattern of life.

A Walk on a Sunday Afternoon

James Watt was born in Greenock on the Clyde, the fifth child of a ship's carpenter. His health was so poor that he was unable to play with other children or to go to school. He learnt his three R's at home from his mother. He would suffer for weeks at a time from headaches, unable to leave his room. But when he was well enough to go out he would visit his father's workshop, where he soon began to work on his own account, repairing nautical instruments. He read eagerly every book he could get, especially works on natural science.

When he was fifteen he had learnt almost all that was known about physics at that time—around 1750. His father sent him to Glasgow to Professor Dick to study advanced mechanics. Dick called himself an optician, but in addition to spectacles and telescopes he made fish-hooks and violins.

Later, Professor Dick procured a shop and a laboratory in the University building for Watt, where he could work as an instrument-maker and "machine doctor".

The shop did pretty well. Watt accepted all kinds of repairs.

Then one day in 1763 the famous Professor Anderson, who taught natural science at Glasgow University, brought him a small model of a Newcomen steam-engine, which he needed for his lectures. It would not work properly; the piston would make only a few strokes and then stop. James Watt felt that this was exactly the sort of problem he loved to tackle.

The machine was simple. It consisted of a small boiler where the steam was produced, and a cylinder with a piston and rod. At the bottom of the cylinder there were two valves; one admitted the steam which pushed up the piston, and the other opened to admit a jet of cold water as soon as the piston had reached its highest point. This cooled the steam and turned it to water; and as steam takes up 1,700 times more space than water, a vacuum was formed underneath the piston, and it was pushed down by the surrounding air in its endeavour to fill the vacuum.

Watt soon found what was wrong with the machine. It produced too little steam and needed too much fuel. Perhaps, Watt thought, the steam was not used efficiently enough? He felt that Newcomen's method of spraying cold water into the cylinder to condense the steam was a clumsy way of producing a vacuum. Some different method must be possible!

"One Sunday afternoon in 1765," James Watt wrote later, "I had gone for a walk and my thoughts turning naturally to the experiments I had been engaged in for saving heat in the cylinder, the idea occurred to me that, as steam was an elastic vapour, it would expand, and rush into a previously exhausted space; and that if I were to produce a vacuum in a separate vessel, and open a communication between this and the steam in the cylinder, such would be the result."

This meant that the temperature in the cylinder did not have to be lowered to condensation point with every stroke of the piston, but the condensation could take place in another part of the machine.

The success of this device, the separate condenser, surprised Watt himself. The engine now worked four times as long on the same quantity of fuel!

Another great improvement was Watt's idea to make the piston move not only up, but also down by steam pressure in combination with the action of the vacuum: by making the steam enter the cylinder alternately above and below the piston he forced it up and down. In this way Watt had created an efficient machine, ready to be used in the service of humanity.

The First Steamships

But mankind knew nothing of its good fortune—nothing of the little model in James Watt's workshop in Glasgow.

The reason was that Europe was still living in the feudal age. The classes—princes, nobility, and clergy—that ruled the countries and took the profits of rulership had all they needed in abundance, wrung from the labour of the "lower classes", the peasants and artisans. Why, then, should there be such a thing as labour-saving machinery, which would only tend to make them lazy, to put dangerous ideas into their heads, and to provide them with "luxuries" which the ruling classes wanted to keep for themselves?

But no power on earth could have stopped the progress and development of society. A new social layer, the middle classes, had begun to stir and struggle for freedom, led by men of energy and intelligence who realized that the steam-engine was the powerful weapon which could bring about a reform of society—an industrial revolution.

Among these men was a manufacturer of Soho, near Birmingham, Matthias Boulton. He offered to make James Watt his partner, and together they proceeded to build the first steam-engine factory in the world.

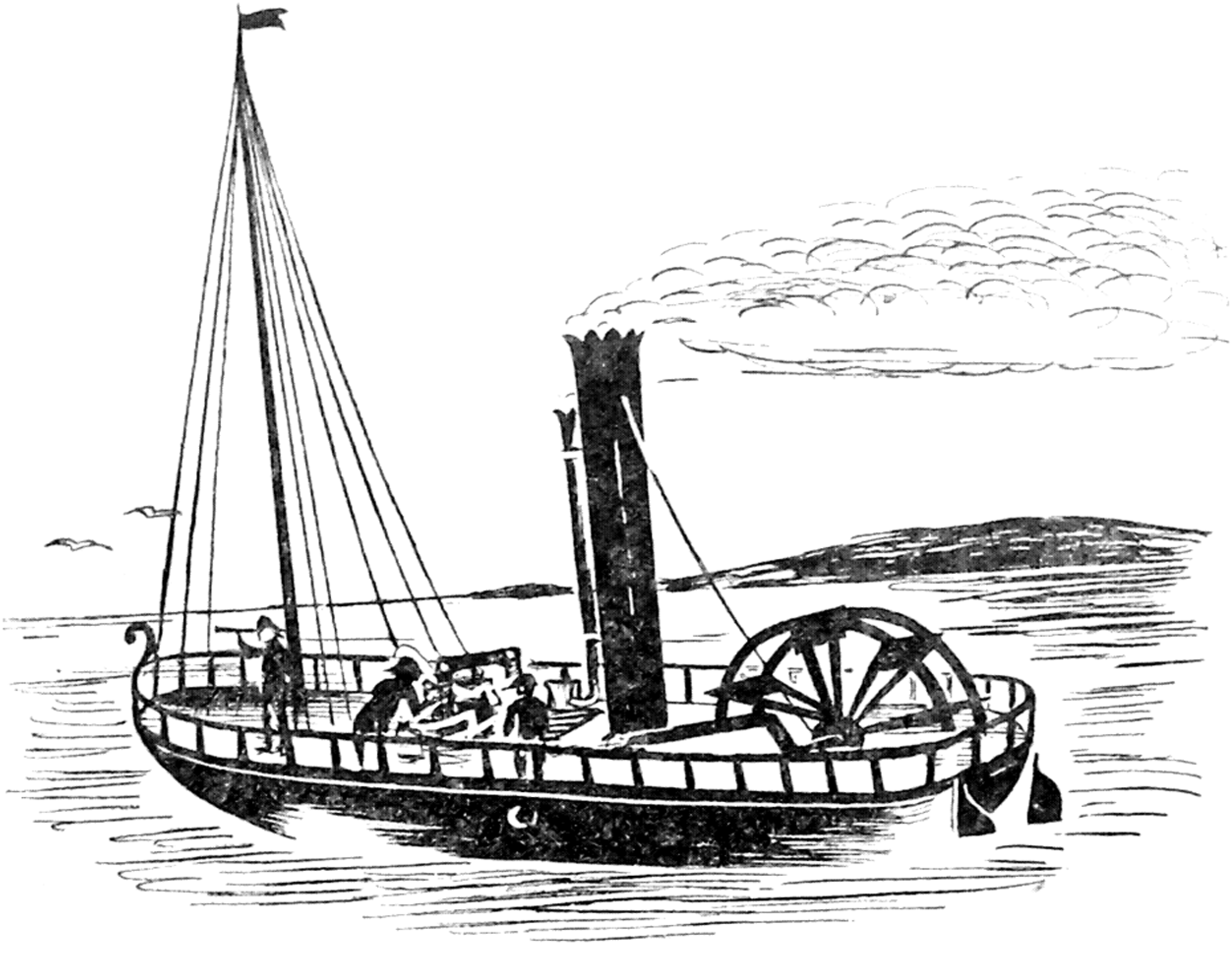
Very soon the works of Boulton and Watt became famous and engineers came from all over Europe and America to see the fabulous new steam-engine, and to place orders for it. A few years later, a steam-engine lifted the first cages loaded with coal from the shaft of a mine, the first oil mill was converted for the use of steam power, and the first steam hammer crashed down on its giant anvil.

The firm of Boulton and Watt began to make money, and gradually James Watt got used to the strange feeling that he no longer had to work for his immediate wants.

When his master patent expired in 1800, Watt, then 64 years old, decided to retire. But he lived to the ripe old age of 83, dying peacefully in 1819.

He had lived long enough to watch the early years of the Machine Age and the beginning of transport by steam. Denis Papin's idea of a steamship was taken up again and again by ambitious inventors, but only James Watt's machine offered any practical prospect of using steam power for this purpose.

It was left to an American to prove that the steamship was the only possible means of transport by sea in the foreseeable future. His name was Robert Fulton, and if he succeeded in the face of enmity and bad luck, this was mainly due to the hard-headedness and dogged energy which he shared with so many of his compatriots. He was no idealist who wanted mankind to benefit from a great invention; he was an ambitious inventor and engineer bent on success. He had started his career as a painter in Pennsylvania, then went to England to study art, but switched to engineering, built a viaduct over the River Dee, wrote a book on the modernization of canal traffic, and then followed a summons to Paris to execute a colossal painting for a panorama.



Fulton's steamboat (1807)

It was then that he took an interest in ships; but his first idea was to build a submarine for the French so that Napoleon could attack the British *under* water: for he had found them invincible *above* water. Napoleon showed great interest in Fulton's plans, but in the end the French naval authorities decided not to embark on such a barbaric method of warfare.

Fulton had made friends with the American ambassador in Paris, Robert Livingston, who was not only a steamship enthusiast but also had the means to have them built.

They bought an old Watt engine and built a ship around it, but the engine was too heavy and the bottom of the boat dropped out. Another engine was bought, another boat built. In the meantime, Fulton sought an audience of Napoleon to ask for his assistance. The great man had at first been very interested in the inventor's plans, but then his scientists submitted a very sceptical report, and when the easily-biased Napoleon saw Fulton he asked him with scathing sarcasm, "So you want to drive a ship with cigar smoke!"

Nevertheless, Fulton and Livingston went ahead with their trials of the new ship. It steamed up and down the Seine with a few passengers on board, watched by an enthusiastic crowd of Parisians who had come to see a ship being driven by "heated water" instead of wind and sails.

Shortly afterwards, Livingston and Fulton obtained some money for further steamship experiments from the American government, and decided to return to the States. On his way back, Fulton paid a visit to Boulton and Watt in Soho, and ordered a 20 h.p. engine. While it was being built, the hull of the first true steamship was taking shape in a shipyard on East River, New York. It was launched in the spring of 1807, a paddle-steamer of 150 tons, called the *Clermont* after Livingston's birthplace.

On August 17, 1807, the *Clermont* undertook her first trip from New York up the Hudson to Albany, a distance of 150 miles. She reached her destination in 32 hours. The strange and frightening spectacle of the first steamship—"the horrible monster which was marching on the waves and lighting its path by vomiting fire", as a newspaperman described it—terrified the crews of other ships on the Hudson. "Fulton's Folly", America called the *Clermont*. But she brought fame and financial success to Fulton and Livingston.

Fulton built 15 more steamships, some of them men-of-war for the American government, before he died in 1815, at the age of only 50, just four years before the first ship crossed the Atlantic with the help of steam power.

The Steam Circus

When James Watt's patent expired in 1800 and anybody was free to build steam-engines if they so desired, Richard Trevithick, a mining engineer, who loved steam-engines, built some models in his workshop and put them on wheels. At Camborne, Cornwall, where he lived, he used to show his friends his little steam cars, which ran around a table. His dream was to build a large one for road transport, and this he did in 1801. It was a giant iron coach without a horse; the chimney was in the middle, and around it were seats for the passengers. The driver stood at the steering-wheel, and behind him was a platform for the stoker. Trevithick called the vehicle "Puffing Devil".

On Boxing Day, 1801, he invited his friends for the first ride on a steam car. After moving at a smart pace for 300 yards, the engine broke down, and the car was pulled into the coach-house of an inn, where Trevithick and his friends treated themselves to roast goose and wine. Suddenly an acrid smell came in by the window: Trevithick had forgotten to put out the fire, the boiler of the car had become dry and the red-hot engine had set the coach-house alight. Both vehicle and coach-house were completely destroyed!

Trevithick, however, proceeded to build another steam-coach. He drove it all the way to London, but by then the engine had outlived its usefulness and was built into an old mill.

In 1804, he constructed a locomotive for the Pen-y-Darran ironworks in Wales. He set it on rails, and it pulled 10 tons of iron ore and 70 passengers in five wagons at 5 m.p.h. along a 10-mile line. But it did not work long because the rails were not good enough and wore out the wheels.

One of the most interested observers of that locomotive was a young friend of Trevithick's, a Northumbrian stoker by the name of George Stephenson, who frequently visited the inventor, bringing with him his wife and small son, Robert. Trevithick often gave the little boy a ride on his knees, but with the father he discussed the steam-engine as a means of transport.

In the summer of 1808, in an attempt to arouse public interest, Richard Trevithick opened a "Steam Circus" in Euston Square, London, not far from the place where, years later, Euston Station was built. It was a roundabout in the form of a train running on rails, and a trip cost a shilling. Business was not bad; Londoners crowded to the Steam Circus. But after a few weeks one of the wheels of the locomotive broke, the engine overturned, and the enterprise came to an end. Luckily, nobody was seriously hurt.

In 1813, Trevithick went to South America, but had little luck. He died a poor man in 1833.

Meanwhile, his friend George Stephenson had taken up the struggle for the railway and steam-driven transport. He was born at Wylan-on-Tyne in 1781; his father, "Old Bob", was a stoker working on the pumping machine in the local mine, earning 12 shillings a week. None of the six children went to school; they all had to try to make some money to keep the family from starvation. George's first job, at the age of eight, was to take care of the cows and geese of a widow who lived near a little horse-operated railway for transporting coal; for twopence per day, he had to see that the animals did not stray on to the line. That railway made a deep impression on the boy, and was the starting-point of many of his thoughts and ideas. At nine, he had to go down the mine as a coal sorter; then he became an assistant stoker and worked with his father.

At 17, he was made engine-boy on the Newcomen pump which Old Bob stoked; he was supposed to fetch an engineer if something went wrong with the machine, but he always managed to get it going again by carrying out the repairs himself. At last he earned enough money to attend an evening school—for at 18 he could still neither read nor write. It was one of the proudest days in his life when he was able to sign his own name at the age of 19.

He worked in a number of collieries, always trying to be as near as possible to the engines. Soon he knew more about them than the engineers who had studied mechanics and science. At Killingworth, West Moor, where he worked for many years as an engine-man and a brakesman, he was called the "engine doctor". Now that he made more money he decided to let his young son, Robert, have a better education than he himself had had. Robert later repaid his father by passing on to him much of what he learned, and often the two were seen in a huddle over a book or drawing.

Lord Ravensworth, the owner of the Killingworth Colliery, was a man whose interest in his mine was not limited to making as much money as possible out of it. When he heard that his "engine doctor" was working on plans for a "travelling machine" to take the place of the horses pulling the coal wagons along the "tramroad" from the pithead to the canal, he had a word with him. Stephenson told his Lordship that he had made intensive studies of the problems of steam-engines, wagons, tram-roads, wheels, friction, and gravity. He had come to the conclusion that the traffic of the future would be largely worked by locomotives and would run on rails.

A Stoker in Parliament

To Stephenson's great joy, Lord Ravensworth asked him to build such an engine. He flung himself into his new work with enthusiasm. Within a few months, his first locomotive—it was named *Blücher*—chugged along the railway lines in the colliery, carrying up to 30 tons of coal at a speed of four miles an hour. That was in 1814. A year later, he built his second engine, which was more efficient and much cheaper to work than horses.

Other mine-owners commissioned Stephenson to build such engines for their collieries, and enabled him to set up his own works. But there was hardly any public interest in these machines; they were confined to the mines, like the steam-engines in the previous century. But one such colliery railway at last bridged the gap between the idea of transporting coal by steam power and that of carrying passengers—the line between Stockton and Darlington, in the Bishop Auckland valley. George Stephenson offered to build a locomotive that would do the work of 59 horses. When the line was opened in September, 1825, the engine, driven by Stephenson himself, pulled a train of 38 wagons, 22 of them filled with passengers, altogether 450 people. For the first time, a great number of people were to experience the thrill of being transported by that new, mysterious power—steam.

Many of them must have felt ill at ease; all kinds of warnings had been uttered by the know-alls and wiseacres. But after the first anxious minutes they began to feel the wonderful sensation of speed. They saw trees and houses and meadows rushing past them, horses shying, cows lowing in fear, and along the streets they saw the miners and farmers staring at the wonder of the age, children waving, and mothers trying to keep them at a safe distance. Spitting and hissing, pounding and roaring, the train rushed on, faster than the fastest mail-coach.

Early railway

It was a complete victory for Stephenson.

Meanwhile, the plan to build a long passenger and freight line from one big town to another—from Manchester to Liverpool—had been submitted to Parliament. A hard battle was to be expected, for the railway would mean much less business for the Bridgewater Canal, which connected the two cities and especially the Duke of Bridgewater's mines with the port. A few of the most influential people in the country were shareholders in that canal, and saw their profits threatened by that stoker from Northumberland. They thought it might be a good idea to make Stephenson himself come to a session of the Parliamentary committee dealing with the matter—and spoil his case by making himself ridiculous in Parliament.

Stephenson went to Westminster, a figure rarely seen in those precincts: a man of the people who made no secret of his origin, a powerful man in middle age, strong as a horse, carelessly dressed, and with huge hands. His eyes were bright, his smile optimistic. A splendid fellow to any unprejudiced eye; a disgusting person to the minds of his opponents. Even his friends in Parliament feared that his straightforwardness would ruin everything.

His cross-examination began. "I was not long in it," Stephenson said later, "before I began to wish for a hole to creep out!" The objections and questions which were put forward might indeed have driven anybody to despair: cows would cease to give milk and hens to lay eggs after they had seen the terrible spectacle of a railway train; the poisoned air from the funnel would kill the birds; houses would be set on fire by sparks from the engine; horses would find no more work and would die out, oats and hay would be unsaleable, coachmen and innkeepers along the roads would become beggars; the roads would be deserted, and become infested by highwaymen; the boilers of the locomotives would burst and the hot water scald the passengers to death; or they would become mad because no one could stand a speed of more than 10 miles an hour!

One by one, Stephenson tried to refute these objections to his railway. He was even asked if he was a foreigner, because of his North Country accent. Shying horses? Well, there are some horses that would shy at a wheelbarrow, he said. Someone reminded him that a locomotive made by another engineer had burst because a drunken attendant had allowed the steam pressure to increase beyond the danger point.

"You must blame the beer for that," grinned Stephenson, "not the steam!"

"And if a cow happened to stray upon the line and get in the way of the engine—would that not be very awkward?" he was asked.

"Very awkward indeed," replied Stephenson in his broad Northumbrian, "for the coo!"

Yet he lost his case. For he was unwise enough to declare: "I consider that speeds up to 12 miles an hour are perfectly practicable!" That made him in the eyes of the committee members a boastful swindler—or a dangerous fool.

The Rainhill Race

A year had to pass before another Railway Bill could be introduced in Parliament. The good record of the Darlington-Stockton line had helped to create a favourable atmosphere for Stephenson. Meanwhile, the line from Manchester to Liverpool had been surveyed—with some difficulty, for the canal managers had recruited a whole army of farmers with shotguns to take pot-shots at Stephenson's surveyors. The quietest time for them was on Sunday mornings when everybody was in church listening to the parsons preaching against the railway. Once Stephenson surveyed a stretch in a moonlit night; but his opponents turned out in force and drove him away. He resorted to a ruse; he had salvoes fired from one tract of the canal which was already surveyed, and while the whole force of farmers went in that direction to search for the intruders he did his work elsewhere.

In Parliament, however, Stephenson's supporters were at last in the majority, and the Bill was passed in the Commons and the Lords. Work on the line began at once; Stephenson recalled his son, Robert, from America, where he had been building bridges, to help him with the construction work, especially across Chat Moss, the most difficult part. The young engineer solved the problem brilliantly.

British fairness demanded that the contract for locomotives for the new line should be given as a result of an open competition; Stephenson himself urged that the locomotives of other engineers should be given a chance to compete against his own.

In October, 1829, the famous locomotive race took place at Rainhill, on the now completed line. Thousands of spectators came to witness the great event. There were five engines, Stephenson's own, which he had named "Rocket", and four made by other engineers; but one had to retire quickly from the competition when it was discovered that there was a horse hidden inside the locomotive!

The "Rocket" won with ease, achieving the "incredible" speed of 35 miles an hour. With this wonderful engine, the Manchester-Liverpool line was opened on September 15, 1830.

Soon, steel roads began to stretch across every county, accelerating and increasing the flow of goods and the exchange of travellers to undreamt-of heights. Stephenson had won a great victory over stupidity and backwardness: the triumph of steam power was his personal triumph. For fifteen years after the opening of the Liverpool-Manchester line he continued to build locomotives for numerous countries; then, in 1845, he retired to his home near Chesterfield. He was happiest when he could find a worthy opponent for a wrestling bout, for the ex-stoker was still a Hercules even in old age. He died in 1848 at the age of sixty-seven.

Atomic Energy and the Steam Turbine

Even before Papin's time an Italian inventor, Branca, built a small machine in which the power of a steam jet was used to turn a paddle wheel—the first turbine, from the Italian word *turbino*, which means whirlwind. It was, in principle, a much simpler system of using steam power than the complicated piston engine invented by Papin and perfected by Watt. For a long time, engineers tried to build an efficient steam turbine, but they all failed. At last, however, the British engineer Sir Charles Algernon Parsons designed such a machine in 1884, using a whole battery of wheels with hundreds of steel blades, all turning on one shaft, and enclosed in a metal casing.

The steam turbine has found many important applications in transport and industry. It generates our electricity, it drives many ships and railway engines. Yet its most important application is still to come: for there is little doubt that the steam turbine will be the means by which we shall enjoy the benefits of atomic energy, and Branca's little contraption will then find a use which even his imaginative brain could not have dreamt of.

Atomic energy—the utilization of the tremendous forces freed by splitting up the nucleus, or kernel, of the atom—is produced in so-called atomic "piles" (*pile* is the French word for battery); it appears in the form of heat, and this heat is used to turn water into steam. And steam is best utilized in a turbine, which can be geared to an electric generator.

Thus the coming of the Atomic Age, at the beginning of which we now stand, will mean the revival of our old friend, the power of steam, for this is still the most convenient way of turning heat into energy.

Chapter Three

THE TAMING OF THE LIGHTNING

TAKE your comb and rub it with a piece of cloth; then hold it near a little scrap of paper. The comb will attract the paper as a magnet attracts a nail. What is the force that is active between the two objects?

It is the same force which makes the light shine in our lamps, which powers an underground train and produces sounds in our radio loudspeakers.

The material of which your comb is made is a new industrial product called plastic. But there are some similar materials which occur in nature; the best-known of them is amber. About 600 B.C. the Greek philosopher, Thales of Miletos, discovered that if he rubbed amber with a piece of cloth it attracted small objects. Now the Greek word for amber is *elektron*, and therefore Thales called that mysterious power "the electric".

The women in ancient Greece made use of his discovery by decorating their spinning-wheels with pieces of amber: when the woollen threads rubbed against the amber, it attracted them at first and then pushed them away. That little spectacle helped to enliven the boring job of spinning. Of course, only wealthy women could afford to buy amber because it was a precious stone which had to be brought all the way from the Baltic coast.

More than two thousand years passed before scientists began to inquire into that mysterious force. The first physicist who studied it—and coined the word electricity—was Sir William Gilbert, Queen Elizabeth's doctor. He discovered that the attraction of the amber came from the same source as the crackling and the tiny sparks in human hair when it is being combed; therefore, friction must be a way of producing electricity.

He built an "electric machine", a large disc spinning between brushes, which made sparks leap between two metal balls—a favourite toy in polite seventeenth-century society. But another century-and-a-half passed before research into electricity was carried a decisive step further. In 1746, the Dutch scientist, Cunaeus, of Leyden, built his famous jar: a water-filled vessel with a metal knob on top, which he connected with Gilbert's "electric machine". After he had spun the disc rapidly for a few moments he stopped, and disconnected it from the jar; yet when he touched the knob of the jar he received such a powerful shock that he fell down! He realized that he had found a way of storing up electricity.

The Kite and the Key

The next scientist to take up the study of electricity was Benjamin Franklin, born in Boston, Massachusetts, in 1706, the fifteenth child of an English immigrant, a soap-boiler.

Not until he was well in his thirties did he take up the study of natural phenomena, and he was over forty when he came to the conclusion that thunderstorms were simply a large replica of what happened when Cunaeus touched his Leyden jar—a discharge of electricity between two objects with different electrical potentials, such as a cloud and the earth. He saw that the discharging spark, the lightning, tended to strike high buildings and trees, which gave him the idea of trying to attract this force deliberately to the earth in a way that no harm would be done by the discharge.

In the summer of 1752 he made his famous experiment, fastening an iron spike to a silken kite, and holding the end of the kite string by an iron key. The experiment was more dangerous than he realized, and might have killed him easily. With his son he went into a meadow near Philadelphia and flew the kite while a thunderstorm was approaching. He wanted to prove his theory about the electrical discharge, and found that he was right—a spark

Electricity: Benjamin Franklin's experiment with the kite and the key (1752)

sprang from the key to his wrist. Had the lightning struck his kite he would have lost his life.

His next experiment was the fastening of an iron bar to the outer wall of his house; through it he charged a Leyden jar with atmospheric electricity.

At this point of his research work he was appointed to the office of Postmaster-General of all the British Colonies in North America, and for several years found no time for further experiments. Only in 1760 did he put up the first practical lightning-conductor on the house of a Philadelphia merchant. It is most interesting that Franklin believed that a continual radiation of electricity from the earth through the metal spike at the top of the conductor would take place, producing an equalization of the potentials in the air and on the earth so that the violent discharge of a stroke of lightning would be avoided; the modern theory, however, is that the conductor does in fact attract the electricity from the clouds by making the surrounding air an electric conductor, thus offering the electrical charge of the cloud the path for a quiet equalization of potentials. But what ever Franklin's theory was—his lightning conductor has been a great boon to mankind.

Politics interfered again with his scientific work. The great struggle for the independence of the Colonies had begun, and he was sent to London to protest, in the name of the settlers, against the burden of taxation imposed by the British Government. In 1776 he helped George Washington and the other American leaders to draw up the Declaration of Independence, and eventually he was sent to France as the first Ambassador of the United States. Meanwhile, every public building in Philadelphia—which was the first capital of the U.S.A.—had been equipped with one of Franklin's lightning conductors, with one exception: the French Embassy. And that very building was struck by lightning in 1782, and an official killed in it. This proved the immense value of Franklin's invention.

Until he died, at the age of 84, Benjamin Franklin went on with his electrical experiments.

The Secret of the Frog's Leg

One evening in 1790 Aloisio Galvani, Professor of Medicine, was lecturing to his students at his home in Bologna. Galvani and his audience were in the hall of the house, while his wife was preparing the dinner in the adjoining kitchen. She was skinning frogs—her husband's favourite dish—with his scalpel.

As she listened to the Professor's lecture, the scalpel fell from her hand on to the frog's thigh, touching the tin plate at the same time. Suddenly, the skinned thigh made a violent jerk as if it wanted to jump off the plate.

Signora Galvani screamed. Her first impulse was to stab the frog, which she supposed to be still alive. But the thigh relaxed and moved no more.

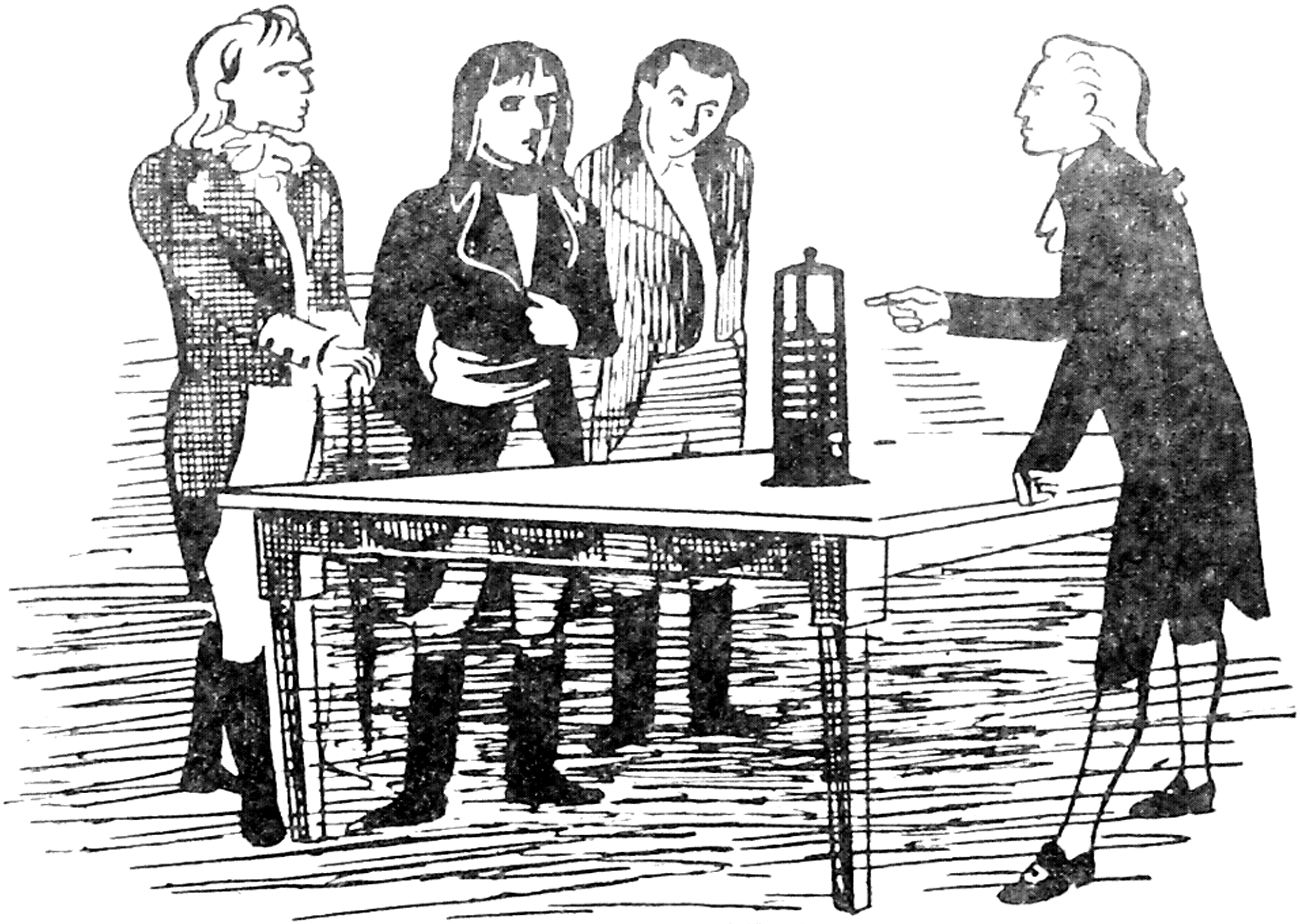
"What's all that noise?" asked Professor Galvani indignantly.

She told him what had happened, and touched the thigh in the same way as before, and again it jerked.

Galvani, who did not dare to let his students know that he was perplexed by some natural phenomenon he could not explain, exclaimed at once, "Wife, I have made a great discovery—animal electricity, the primary source of life!"

He believed the frog's thigh muscles were something like small Leyden jars; consequently, he made many complicated and unsystematic experiments with frogs, but failed to get any results because he had no idea of what he was actually looking for. These animal experiments became a fashion, and for a time the poor frog family, which had become involved in electrical research by that unlucky chance, was in danger of extermination.

What had really happened in the frog's jerking thigh? To the day of his death, Professor Galvani clung to his "animal electricity" theory. But a greater man than he, another Italian scientist by the name of Alessandro Volta, solved the mystery. Volta, who was professor of physics at Pavia, declared that there was no such thing as animal electricity or the primary source of life in dead frogs. He assigned them their true and more modest place within the field of electricity. He realized that the main factors in that scene in Signora Galvani's kitchen were the two different metals, the steel of the scalpel and the tin of the plate! Volta demonstrated that whenever moisture comes



Volta explains to Napoleon his electrical battery between two different metals an electrical potential is created. The frog's thighs, which had been soaked in salt water, merely played the part of conductors of moisture between the two metals, and their muscles jerked under the impact of the electric current that flowed through them.

For Volta it was but a single step from this discovery to its practical use. He invented the first source of current electricity, the "voltaic pile", the electric battery: sheets of thin copper and zinc, separated by layers of acid-soaked paper. Like many great men he was modest, and insisted on calling his invention the "galvanic element" and the phenomenon he had correctly explained the "galvanic current"—in honour of a man who had not earned his fame.

With the battery, with its new kind of current electricity that did not spend itself all in a spark or shock but flowed steadily like a current of water, electricity had come to stay, and electrical engineering began its conquest of the world. From 1800, scientists in innumerable laboratories in Europe and America experimented with electricity to discover what useful work it could perform. They found that it could travel from one place to another by wire, that it could produce heat and perhaps even light; one day, they believed, it might be made to carry out heavy work like the steam-engine.

Dr. Jackson's Magic

One day around 1820 Dr. Hans Oerstedt, a Danish physicist, was lecturing in the University of Copenhagen, holding up an electric wire, when it suddenly slipped out of his hand. When he moved to pick it up again he noticed that it had fallen across a compass lying on the table—and that the compass needle, instead of pointing north, had swung completely out of position!

Oerstedt was puzzled. He picked the wire up—and the needle returned to its proper position, pointing north. It did not take him long to find out that there was a very close connection between electricity and magnetism, and he duly wrote a long report about his discovery. The French scientist Ampère read it carefully and repeated Oerstedt's experiments. He found that electricity could indeed produce magnetism. He suggested that much stronger magnetic influence could be exerted by placing the magnetic needle in a coil of wire.

The English physicist Sturgeon went one step further. He found that any piece of soft iron could be turned into a magnet by sticking it into a coil of insulated wire and making an electric current flow through the coil; but the iron would become only a temporary magnet as soon and as long as the current passed through the wire. When the current was shut off the iron was as non-magnetic as before.

Sturgeon built the first electro-magnet. It created a scientific sensation, and Ampère was the first to include such an instrument in his lectures at the Sorbonne and the Académie Française.

A young American, Dr. Charles T. Jackson from Boston, happened to visit Paris and attend one of Ampère's lectures. The electro-magnet fascinated him, and he bought the necessary equipment before starting on his return journey to America. In October, 1832, he boarded the sailing ship *Sully* in Le Havre. One evening he demonstrated the electro-magnet to his fellow-passengers. He produced a piece of soft iron, wound a coil of insulated wire around it, and connected the wire to a galvanic battery. The iron attracted a few nails from the table just like an ordinary magnet; but when Dr. Jackson detached the wire from the battery the nails dropped back on the table.

The passengers laughed and applauded. What a charming scientific toy! But to one of them it meant more—the sudden flash of an idea that was to change everyday life to an unforeseeable extent. His name was Samuel Morse, and if anyone had told him only an hour earlier that he was to become an inventor he would never have believed it. For he was an artist, a painter, and a famous one at that. He was forty years old—an age at which one does not usually change one's profession. He had risen from humble origins, and married a beautiful girl.

But after seven years of happy marriage his wife had died, and he was so distressed that he felt unable to continue his work. He sought oblivion in a long tour of Europe's art centres and museums. Now he was on his way back to America to resume his career. But Dr. Jackson's demonstration of the electro-magnet was to alter the whole course of his life.

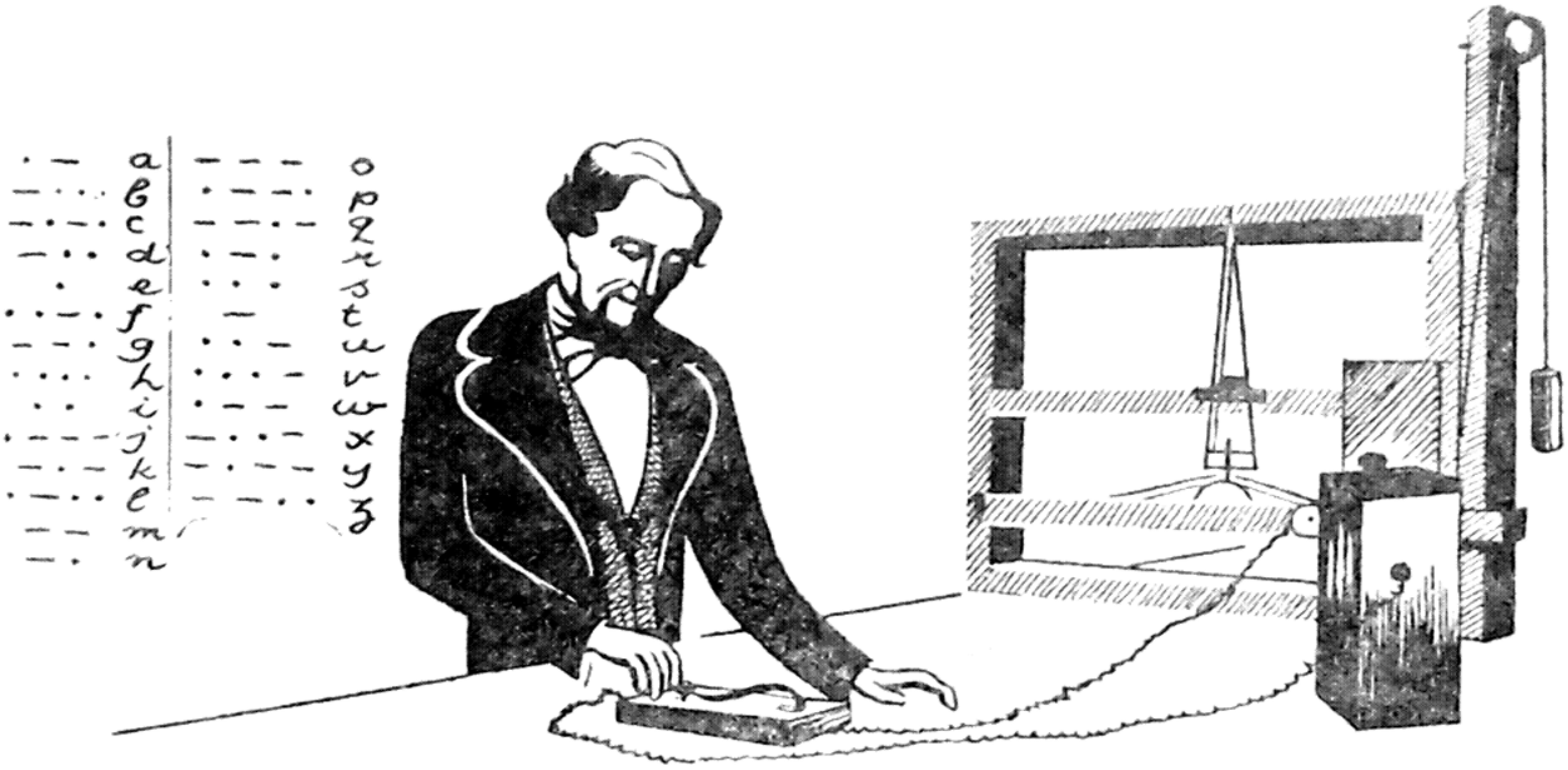
What was the idea that flashed through his mind while watching the experiment?

As such an electric circuit with an electro-magnet, he thought, could be opened and closed at one point, there was no reason why messages might not be transmitted by using the electro-magnet to write them down at another point of the circuit!

A simple idea; but Morse did not realize how difficult its practical application would be for a man like himself who had no technical training and no experience in "selling" an invention to the world. All he knew was that there must be a great need for a modern instrument of communication from one town to another, from one country to another. For two thousand years the speed at which news was transmitted had remained the same.

Birth of the Morse Code

All through the ocean-crossing Morse remained in his cabin, covering his sketch book with drawings of the electric telegraph he was going to build. He was completely obsessed by this idea, and when he at last arrived back in New York he felt no desire to paint, but tried to make a living by giving drawing lessons while working on his invention. If one of his pupils failed to bring the money for the lesson the Professor had little more than tea and biscuits to keep body and soul together.



Morse and his telegraph model built on an easel

He used an old easel as the basis of his first model; the rest of his primitive equipment was an electro-magnet which he had wound himself, a single-cell battery, and the clockwork mechanism of a disused clock. When he closed the circuit by connecting the wire to the battery, the electro-magnet fastened to the easel attracted a piece of iron which served as an armature, and to which he had attached a pencil. Underneath the pencil moved a paper strip pulled along by the clockwork, and the pencil made slanting strokes on it. By opening and closing the circuit at short or long intervals he could produce various kinds of strokes, each kind representing a certain letter of the alphabet.

It all worked, but very unreliably and only at short distances—as soon as he extended the wire over more than 12 or 15 yards the current became too weak to operate the electro-magnet. He wondered how he could cover longer distances, and hit on a brilliant idea: the relay, which is still one of the most important electrical devices. "Relay" was the term used for a post station where the tired coach horses were replaced by fresh ones. Morse used the same system for his telegraph: when the weak current reached the end of the wire it had only to move the tiny armature of a small electro-magnet—and a new circuit with a fresh battery was closed. In this way, a large number of circuits could be linked to carry the telegraphic signals to any distance.

Meanwhile, friends had helped Morse to find a position as an art professor at the New York City University; now he had at least enough to eat. He showed his relay to some students, and one of them, Alfred Vail, was so enthusiastic about it that he offered not only to help Morse with building a workable model of his telegraph, but also to get his father, an ironworks owner in New Jersey, to invest some money in the invention.

Now the road ahead seemed to be clear. The first thing Vail did was to design a practical "key" for closing and breaking the circuit—the "Morse Key" which has essentially remained the same. A new, efficient model of the telegraph was built with Vail senior's money, and the first demonstration given with it in the University hall in September, 1837. But the signals used by Morse, the slanting strokes, proved to be too cumbersome. So one day Morse took a newspaper, counting with Vail the frequency of the letters of the alphabet. "E" turned out to be the most frequent one; Morse alloted it a short stroke, a "dot", in the new code he was devising. Then came the "T"; it was given a long signal, a "dash". So they went through the whole alphabet, including the numbers and punctuation marks.

Morse's dot-and-dash alphabet, the "Morse Code", has remained unaltered to this day; its importance has been immeasurably increased with the introduction of wireless telegraphy. It was published in January, 1838, on the blackboard of the New York City University.

Five Needles and a Murderer

The telegraph was demonstrated before Congress in Washington by Morse and Vail, and a Bill was drawn up to ask for public money to build the first telegraph line from Washington to Baltimore.

But just then the country was in the grip of an economic crisis, and Congress had other worries than that of finding money for the first telegraph line.

Morse's friends failed him. His applications were not answered. Months passed, then years; still he tried to arouse interest in his invention, with the result that he became to be regarded as a harmless madman. More than ten years after that crossing on board the *Sully* he sent a last, despairing appeal to Congress: "If I do not get a reply now I shall return for good to my brushes and have nothing more to do with the telegraph."

At last Congress responded. The "Morse Bill" was placed as the last item on the agenda of March 3, 1843. Morse himself attended the session until after midnight and then went home because he felt that all was lost, and that the House was against the telegraph; he was unable to bear the disappointment which he thought was inevitable. He counted the money he had left: it was 37½ cents.

In the morning, a friend burst into his room. "Congratulations, Professor! You have won! The Bill was passed with a majority of 89 to 83!"

Work began at once on the 40-mile stretch from Washington to Baltimore. On May 24, 1844, the world's first telegraph line was opened, with Morse at one end and Vail at the other. But there were no telegrams to transmit; no one really knew what to do with this new means of communication.

Two days later, however, an important piece of news was telegraphed from Baltimore to Washington. No one would believe that the telegraph could transmit news at such speed; but when it was confirmed by post many hours later, Morse was the Man of the Day. From now on he never looked back until his death, at the age of 81, in 1872. He died with his hand still on the Morse key that connected his country home near New York with every telegraph station in the world.

In England, however, the Morse system was not introduced for quite a while; for that country had its own telegraph, invented by Sir William Cooke and Sir Charles Wheatstone, two physicists. In 1837 they built their telegraph apparatus, which had five magnetic needles and as many wires; when a current was sent along one of the wires the corresponding needle moved on the panel on which it was fixed, and which showed the letters of the alphabet. The individual letters were indicated by combinations of the positions of the five needles.

The first telegraph line was built along the Great Western Railway from Paddington to Slough. Just like Morse's telegraph, however, it wanted a special opportunity to demonstrate what it could achieve. That opportunity came on January 1, 1845, when a murderer was arrested in London after leaving the train from Slough—the police had been notified by telegraph.

A Hot Day in Boston

Alexander Graham Bell, born in Edinburgh but educated in Boston, was a teacher of deaf-mutes. One of his pupils was pretty Mabel Hubbard, with whom he fell in love. In due course they married, and Mabel's father financed the experiments which Bell took up in two workrooms above an electrical shop in Boston.

He started from the idea of making voice vibrations visible to deaf people by electrical means, and from there to the problem of voice transmission from one place to another was only a short step.

His first model had a transmitter in which a watch-spring was fastened to a gold-beater's skin and held at a short distance from an electro-magnet. When words were spoken against the gold-beater's skin the watch spring vibrated in front of the electro-magnet, thus modulating the current in the wire around it. The modulated current was conducted to the receiver, in which another electro-magnet attracted a steel spring, whose vibrations were communicated to the surrounding air. The apparatus worked—though what was said at one end was hardly intelligible at the other.

One hot day in June, 1875, Bell was busy tinkering with the steel spring in the receiver while his assistant, a young man by the name of Watson, was lazily plucking the spring in the transmitter in the other room. It had got stuck, and Watson tried to free it. Suddenly Bell called out, "Watson, I say, what have you been doing? Leave everything as it is and let me see!"

Some new, feeble sound had arrested Bell's attention. No one else but the inventor would have noticed it; but he recognized at once the critical importance of that sound. When he saw the transmitter he understood what had happened—Chance was showing him the right way.

What had happened? The spring that had got stuck and was being plucked by Watson produced a continuous current in the electro-magnet, while the moving spring had so far only produced intermittent modulations. The permanently closed circuit, accidentally brought about by the immovable spring, was the solution.

For nine months, Bell and Watson worked on the new model. The goldbeater's skin was replaced by a thin plate of iron, the electro-magnets became permanent magnets with wire coils around them, and receiver and transmitter were given the handy form of short tubes, one for speaking into and the other for holding to one's ear.

In March, 1876, the telephone was ready for use. The transmitter was in the upper floor, and the receiver installed on the ground floor of the house. The first words spoken into the new instrument—they have become famous—were Bell's informal "Mr. Watson, please come here. I want you." A minute later, Watson stood before Bell—proof enough that the telephone was really working!

Light from a Button Thread

In our story one of the greatest names in the world of invention and discovery has so far been missing—Thomas Alva Edison. But now we cannot keep him out any longer.

The man who took out no less than 2,500 patents during his lifetime was born in 1847 at Milan, a small town on Lake Erie, U.S.A. Already as a boy of eleven he showed his sound business sense—which was to distinguish him later in life from the starry-eyed type of inventor—by growing vegetables for sale. The next step was that he brought his vegetables by train from the nearest big town, Detroit. Then he began to use the time he had to spend on the train by carrying out chemical experiments. He also sold Detroit newspapers at the train stops, and eventually he bought a small printing press and printed his own paper in the luggage van of the train.

A station-master whose child he saved from being run over by a train taught him the Morse Code, and after three months' training he got his first job as a telegraph operator. But he aimed higher in life. With no more than a dollar in his pocket he arrived in New York, and at once Chance offered him an opportunity to prove his technical skill. A "ticker" machine, serving a private telegraph network for informing bankers and stockbrokers of the latest exchange rates in Wall Street, had broken down in the midst of a financial crisis. Edison not only repaired it but devised a better machine. The company bought the patent rights from him for 40,000 dollars.

With this sum he set up his own workshop and began to develop his inventive ideas.

One night in December, 1876, he had been working on a telegraphic "repeater", an instrument for receiving incoming Morse signals automatically and passing them on at increased speed, when suddenly the clockwork mechanism got out of control, and the telegraphic signals on the whirling disc of the machine became audible—they sounded like the babbling of an excited woman's voice. Edison realized that here, in its most primitive form, was a machine that could reproduce sound.

The result was his invention of the phonograph. It consisted of a revolving cylinder covered with a sheet of tinfoil, a needle and a membrane. When the sound waves made the membrane vibrate, the needle, which was attached to it, made impressions on the rotating tinfoil. For the purpose of playing the recorded sound back a large horn was mounted over the membrane.

When this machine was ready to be tried out, Edison spoke against the membrane the first thing that came into his mind—the nursery rhyme, "Mary had a little lamb".

Then the needle was placed back to the starting point, the horn placed over the membrane, and Edison began to turn the cylinder again with the hand-crank.

"Never in all my life have I experienced such a thrill," he confessed. Tinny and faint, but clearly audible, the words of the nursery rhyme came from the horn. The first recording of a man's voice had been made.

The "phonograph", as the inventor called it—only ten years later, when the tinfoil was replaced by a flat caoutchouc disc, the name "gramophone" was coined for the new instrument—was a great success. But he was already busy with another problem.

Arc-lamps had been known for a long time, but they were expensive, dangerous, and needed constant adjustment and attention. Edison had noticed that strips of carbonized paper glowed for a few moments with a bright, incandescent light when an electric current was passed through them. He realized that if some more suitable material were placed in a vacuum tube the light would shine much longer.

He searched for that material with infinite patience and resourcefulness. It had to be carbonized to be made to glow in the vacuum bulb. He carbonized everything he could lay hands on at his laboratory in Menlo Park.

One night when he was wondering what to carbonize next—it was late at night and he was sitting at his desk—his eye fell on a button on his jacket that was coming loose. He pulled it off absent-mindedly, and fingered the bit of thread still hanging from the jacket. "Why not try ordinary sewing-thread?" he thought, and went out into the laboratory where rows of glass bulbs from which the air had been exhausted were hanging from test racks. The thread was carbonized and carefully placed in a bulb. Edison switched the current on. The carbonized thread began to glow with a pleasant, yellowish light—and continued to glow. It did not go out like the rest of the samples that had been tested. It glowed for forty hours. The incandescent lamp was born.

Faraday in a London Park

Inventing the incandescent lamp was one thing; lighting up whole towns with it was quite another. In theory, the problem had been solved by Michael Faraday, the great English physicist. He repeated, in his laboratory at the Royal Institution in London, all the experiments with the electro-magnet described by Oerstedt, Sturgeon, and Ampère. But his brilliant mind went further. If electricity, he thought, could produce magnetism—perhaps magnetism could also produce electricity? It was an ingenious piece of reasoning, but for a long time he did not get any further. It was the "How" that eluded him. Every time he went for a walk he carried a little magnet and a coil of wire in his pocket, and he would thoughtfully take them out and look at them from time to time.

At last one day he found the solution. Stopping dead in the midst of an early morning walk through one of London's parks, he saw it in his mind's eye. The way to produce electricity by magnetism was—by motion! When a magnet is thrust into a coil of wire an electric current is produced, flowing in one direction; when the magnet is withdrawn the current flows in the reverse direction. Faraday found that any time a magnetic "field" is crossed by an electric conductor a current is produced—mechanical motion, the motion of the magnet, or of the conductor playing the part of its armature, is turned into electric energy!

As early as 1831, Faraday demonstrated a model of such a generator, or dynamo, to his fellow-scientists. It had a powerful magnet between the poles of which a coil of wire was rotated. As long as Faraday operated it by its hand-crank it produced electricity.

But nearly forty years went by before a really practical generator was built by Edison, first for the production of current to light his Menlo Park laboratory—people came from everywhere to admire the new miracle!—and then to supply the necessary current for the first New York street block to be lit by 2,300 incandescent lamps in September, 1882.

Already in 1879 the visitors to the great industrial exhibition in Berlin were able to watch another modern marvel—a train gliding smoothly and noiselessly along its rails, without a steam-powered engine, without hissing or panting, without smoke or ashes. It was the first electric train, forerunner of hundreds of thousands of vehicles of its kind—underground trains, tramcars, suburban and long-distance express trains; forerunner also of the trolley-bus. Its designer, the German engineer, Siemens, had succeeded in building a really efficient electric motor—the reverse, in fact, of the generator, for it converts the electric current back into mechanical energy by means of an electro-magnet and a coil of wire.

Since that time, electricity has wrought an enormous change in everyday life. Imagine that we had to do without it for only a single week: our entire industry and our systems of communication, much of our transport, and a great deal of our private lives would slow down almost to a dead stop. Yet only three quarters of a century ago Man hardly knew what to do with this mighty force which Nature had put at his disposal. Now he has tamed the lightning.

Chapter Four

THE MAGIC SPINNING WHEEL

In the middle of the eighteenth century, England was still a country of villages and farms, of peasants who knew that they would remain poor to the end of their days, and of rich landowners who lived by the sweat of the farm-workers; between these two classes there were the artisans who supplied the goods that had to be made—and mostly made by hand—and the merchants who imported what was wanted from foreign countries. The large majority of the people lived on the land and by the land, and there was only one really large town, London.

Fly Shuttle and Spinning Jenny

Seventy years later, England had become a country of large towns, and London had grown out of all recognition. But the new towns were not very pleasant to live in. Batteries of tall chimneys blackened the sky with their smoke; big, ugly factories cast their shadows over the dismal streets with their small, airless, badly-built houses in which a new class of people lived—the industrial workers.

How did it happen that England changed from a nation of farmers to a nation of manufacturers?

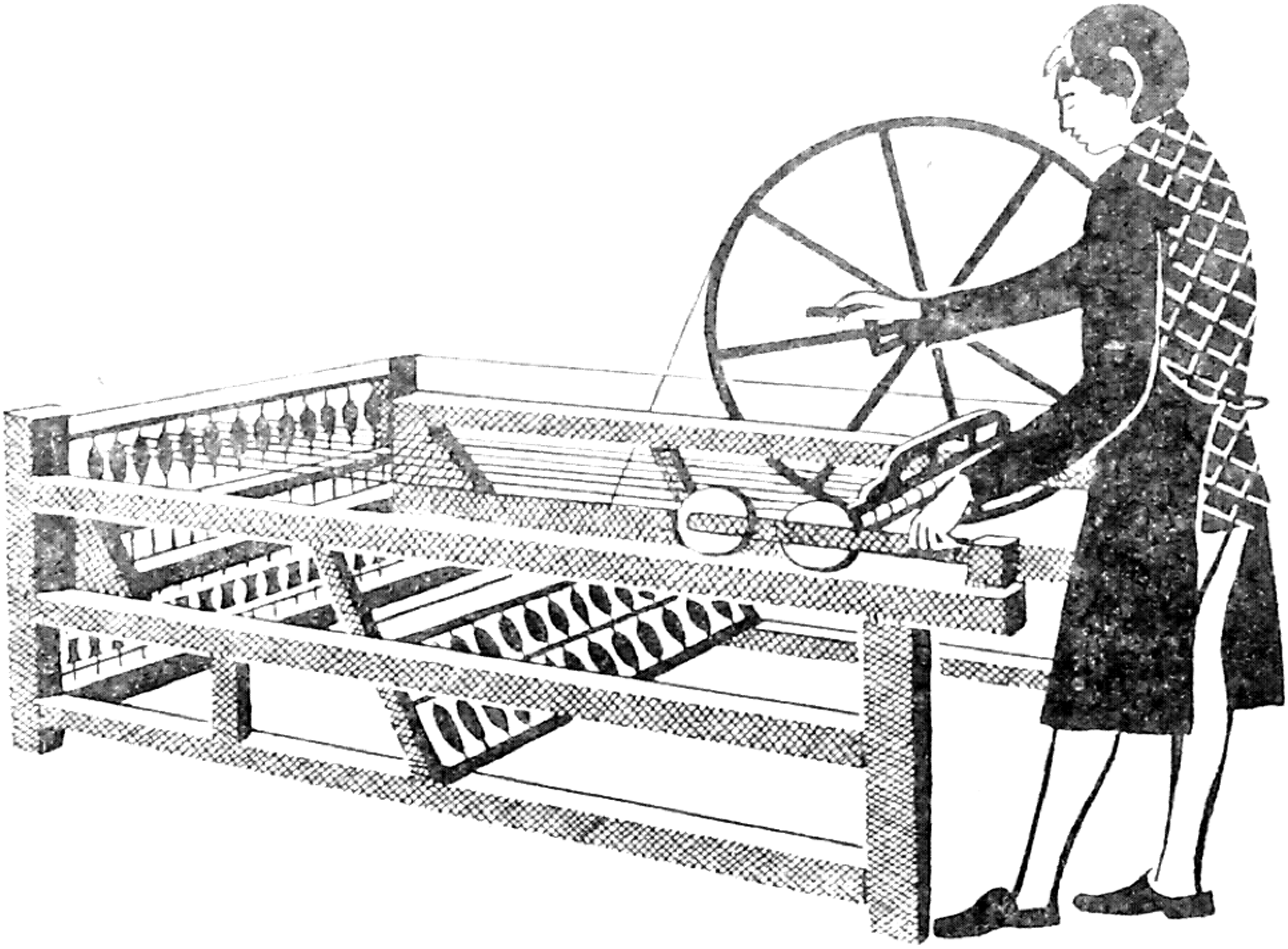
The main reason was that inventors—English inventors—had discovered ways of making goods by machines instead of by hand. The textile industry was the first which changed from an old-fashioned, traditional handicraft to modern mass production. Up to the second half of the eighteenth century, many farmers' wives were still spinning and weaving their own cloth, while in the towns there were large numbers of weavers who supplied the rest of the population and England's overseas colonies with woollen and cotton goods.

Many of those inventors of textile machines and devices were themselves handworkers—not engineers or scientists. John Kay was the first of them, a poor weaver of Bury in Lancashire. Throwing the shuttle forward and backward, working the pedals, tugging down the heavy beater which tightened the woof thread against the cloth already woven, he often wondered if there was no way of making the whole operation less tiresome. It was most of all the throwing of the shuttle which made his arms ache.

He thought of a neat device to make this part of the labour of weaving easier, and invented what was later called the "fly shuttle": a little box on either side of the loom, where the shuttle remained between its journeys across the warp threads. Each box also had a little rod, one end of which was fastened to a cord. When the cord was pulled, the rod hit the shuttle and made it "fly" across the loom to the other side and into the other little box. Then the cord on the other side was pulled and the shuttle flew back again. Kay fastened the two cords to a single handle, and by operating it he could make the shuttle travel either way without any effort.

The effect was that he could work much faster—and the other weavers of Bury were afraid that the fly shuttle, which Kay had patented in 1733, would make so much cloth that fewer weavers would be wanted. There was a riot, and an angry crowd of weavers broke into his house. John Kay himself, who barely escaped with his life, never returned to Bury, but went first to Leeds and later to France, where he died penniless.

Thirty-five years after Kay had invented the fly shuttle, another poor weaver suffered a similar fate as a result of another important invention. James Hargreaves, of Blackburn, was a good weaver, but he was often idle because he ran out of yarn—his only "supplier" being his wife, Jenny, who spun as much as her fingers could stand. One day, one of their seven children upset the spinning wheel by accident, and Hargreaves saw that the wheel went on rotating by its own momentum. "Why couldn't it turn two spindles instead of only one?" he asked himself. "It could make twice as much yarn for me!"



Hargreaves's "Spinning Jenny" (1770)

Knowing what had happened to poor John Kay he set to work in complete secrecy. And he found that a single wheel could operate not only two, but eight spindles! He called his machine "Spinning Jenny" in honour of his wife.

Of course the secret leaked out; the other weavers in Blackburn smashed the machine to pieces, and drove Hargreaves and his family out of Blackburn.

He went to Nottingham, and there he built a new machine—not with eight but with thirty spindles! People came and asked him to make such machines for them, which he did; but when he applied for a patent it was refused. So this inventor, too, was not allowed to enjoy the rewards of his ingenious mind.

A Barber's Invention

Richard Arkwright was not a weaver, yet he was a handworker all the same—a barber. He had a little shop in a basement in Bolton around 1750.

He saw a number of spinning jennys and heard the weavers complain that their yarn was not as fine and smooth as that spun by the old, one-yarn method. And he had an idea.

With the help of a watchmaker—for Arkwright had little mechanical skill—he built a machine which produced a better yarn than the spinning jenny, and much faster; for his machine was to be worked the new way, by power. He called it "spinning-frame", but as it was worked by water-power its popular name was eventually "water frame". The machine squeezed the wool or cotton into flat, long strands, and then twisted them into threads.

The barber-inventor knew very well that he was running into trouble. As soon as Bolton's weavers showed signs of anger and fear he, too, moved to Nottingham, and there sought the backing of two wealthy merchants for the erection of his own mill. At the same time—1769—he obtained a patent for the spinning-frame.

His mill, one of the first textile factories, was a great financial success. Other manufacturers built spinning-frames without paying him licence fees, but now he had money enough to go to court and make them pay. He built more factories in Derbyshire, and hired workers to operate the machines. Thus the former barber became the prototype of the textile industrialist—a new class in England's social structure, and a characteristic figure of the Industrial Revolution. He was knighted by King George III, and when he died in 1792 he left over half a million pounds.

The next improvement came again from a poor man's home. Samuel Crompton was a farmer's boy from Bolton; as soon as he left school he had to start spinning yarn.

Lonely and in silence he sat all day by his spinning wheel to produce the amount of yarn which his mother required of him. He had no time to play with other boys of his age.

He was already in his twenties when he heard of Hargreaves's spinning jenny. He saw the inventor and bought such a machine. But when he set it working he was disappointed. The machine was apt to break fine, soft yarn, and could not be used to spin the long threads which were wanted for the warp on the loom, nor could it be made to spin the thin threads needed for the delicate muslin which was beginning to be very popular with young women. Samuel Crompton had to waste much time joining the broken ends of the yarn. He puzzled for hours on end how a more reliable and efficient spinning machine could be made.

The Haunted Attic

Eventually, he thought he had found a solution, and began to build a machine from wood. When he had to buy tools for the job, he earned the necessary money by playing the violin in the orchestra of the Bolton theatre. But he was afraid his own family might ridicule him because of his ambitious fancies, and worked on his model in a disused attic only after nightfall. When his mother and sisters began to hear strange noises in the stillness, they became convinced that the place was haunted. Eventually, plucking up enough courage to investigate, they found the "ghost"—and discovered Samuel's secret.

For five years he worked on his invention, trying to combine the best features of Hargreaves's and Arkwright's inventions. For this reason he called his own machine a "mule"—it was a cross between the spinning jenny and the spinning-frame as a mule is a cross between a donkey and a horse. He completed it in 1779.

The yarn he produced he sold in Bolton. After a while inquisitive weavers and cloth merchants wanted to know how that wonderful yarn was made. They began to spy on Crompton; some sneaked into the house after dark, and others brought ladders and tried to look in by the window. But they failed to discover why the new machine was so efficient. Crompton was, in fact, using rollers such as Arkwright's frame had, and also the system of twisting and stretching the yarn as in Hargreaves's machine; but the rollers and spindles were connected in such a way that the yarn remained slack and without tension while it was spooled in order to avoid breaking. Crompton's mule had 20 spindles; it is still the most important machine in to-day's textile factories, but a modern mule may have up to 1,350 spindles.

The Government made him a gift of £5,000. He invested it in a factory of his own, but being inexperienced in business matters it failed and he lost the money.

He lived to be 74, and spent his last years existing on a very small pension. Nevertheless he was happy enough, finding much consolation in playing the violin. When he died in 1827 England's great change was nearing its completion—thanks to him and the other inventors of textile machines.

The Ridiculous Clergyman

John Kay's fly shuttle had quickened the pace of the weaving machines; the spinning jenny, the spinning-frame, and finally the mule had caught up with, and exceeded, the pace at which the looms could work; now the looms were too slow—the supply of yarn had grown enormously, and the weavers were looking for a quicker machine. The man who made it was not a handworker but a clergyman.

His name was Dr. Edmund Cartwright, and he had never even seen a handloom and knew nothing whatever about weaving. One night in 1784 he happened to get into an argument about machines in a Nottingham inn.

"These new machines are our misfortune," complained one of his friends. "They create unrest and fear. If they hadn't been invented everything would be fine, like in the good old days."

"Nonsense," said another man. "These machines will help millions of people to enjoy the fruits of civilization, instead of living on the brink of starvation. What we need is still more and better machines. For instance, right now we need a machine that can weave cloth; the handloom is too slow. Such a machine would keep the spinners busy and everybody would find enough work."

"A weaving machine? Impossible," said the first man. "Weaving isn't a mechanical thing like spinning. It takes thought, and machines can't think."

"Perhaps you're right," said the Rev. Edmund Cartwright, who so far had only been listening to the discussion. "Machines cannot think, but men can. They can build machines that obey their commands."

"My dear Cartwright," said his friend who was against machines, " you are a good parson, but what do you know about weaving?"

"Nothing at all," said the clergyman, "but I can learn."

From that day on he became a regular visitor to the weavers' cottages. On his journeys he would talk to himself and gesticulate wildly, and people who happened to see him thought he was rather a ridiculous parson and perhaps not quite right in the head. But what Dr. Cartwright was actually doing was to emulate the movements of the loom as the warp separates to let the shuttle pass, and the beater tamps down the threads into an even fabric. In the end he came to the conclusion that there was no part of the weaving process that could not be done by an automatic device.

He knew as little about mechanics as he had known about weaving, but he could sketch his ideas out on pieces of paper. Then he asked a blacksmith and a carpenter to build the machine for him.

It was not a good machine. It was clumsy, and it took two strong men to work it. But it made cloth. He took out a patent—and began to work on an improved model. Three years later, in 1787, it was ready for testing. He took out a second patent. The machine was better but still not yet perfect because it had to be readjusted after each short period of operating. His third model at last was completely satisfactory.

He associated himself with a manufacturer at Manchester, who built a large factory and installed 400 of Cartwright's machines. They were driven by a steam-engine.

One night in 1791 a crowd of angry weavers burnt down his mill and all the looms in it. Meanwhile, unscrupulous manufacturers in other towns infringed his patents, and he had no money to sue them. He found himself faced with enormous debts and with no income.

He was 66 years old when the Government granted him £10,000 for his many contributions to science and industry. He bought a farm in Kent with the money, and there spent the rest of his life.

America Grows Wealthy

The new textile machines, combined with the increasing use of steam power, changed the lives of England's working population to an unexpected extent. Formerly they had laboured in their own homes or in little workshops; the employer brought them their raw material, such as wool or cotton, and collected the finished article; but the introduction of machines made it necessary to build big factories and make the workers go there every day. As there were people enough to man the machines wages were kept at a minimum level, while daily working hours were excessively long—often more than 14. Even children worked in the factories until Parliament passed a law prohibiting it.

The new masses of industrial workers needed more cheap clothing for themselves. Cotton made the cheapest garments. In the Southern States of the U.S.A. a certain sort of cotton was being grown but so much labour was needed to separate the fibre from the seeds by hand that even with the help of negro slaves there was no hope of increasing production.

The man who found the remedy was a young university graduate from Massachusetts, Eli Whitney. When he saw that a slave working all day could clean only a pound of cotton he invented a simple machine, the "cotton gin", which separated the fibre from the seeds mechanically and worked a miraculous change not only in South Carolina but all over the Southern States, exerting a profound influence on the development of the whole of America. Cotton became the country's greatest source of wealth. At the time when Whitney went south in 1792, the country produced only 140,000 lbs. of cotton per year, but in 1800—only a few years after the introduction of the gin—production had risen to 35,000,000 lbs.! Yet Whitney never became rich by his invention, but had much trouble fighting cotton planters who had stolen his idea. After many disappointments he ceased making gins and turned to the mass manufacture of muskets which his country needed. He introduced the modern system of making parts which are so accurate that a gun—or any other product—can be assembled from any set of components, while in the old days a single handworker had made a complete musket from start to finish as best he could.

The Machine Age, the age of mass production, had begun.

Chapter Five

WHEELS ON THE ROAD

THERE is only one absolutely silent vehicle. It can carry a dozen times its own weight, at speeds up to six times greater than that of a running man; yet its motive power is the same as that of the running man. It can be taken almost everywhere, and parked almost everywhere. It needs no supply of fuel. It is the most important means of transport in many countries and towns. It is a modern technical miracle. It's a bicycle.

Birth of the Hobbyhorse

It is difficult to believe that there was once a time when fathers were distressed to discover that their sons showed brilliant technical gifts. Yet this was the case with young Karl Friedrich Christian Ludwig, Baron Drais von Sauerbronn, whose father was a court councillor at Karlsruhe in Baden towards the end of the eighteenth century. The idea of a young man from an aristocratic family becoming anything so vulgar as an engineer being quite out of the question, there were only two careers open to him—the Army and the Civil Service.

Choosing the latter, he began to climb up the bureaucratic ladder slowly and painfully from forest-master's assistant to chamberlain. But one day the inventor in him broke through the official hide of the courtier.

On that day in 1813, the people of Mannheim were given a special treat. They saw 28-year-old Baron Drais racing through the streets on the strangest vehicle they had ever seen. It was a kind of narrow car with two wheels about 30 inches in diameter, one running in the track of the other, and connected by a wooden beam; the beam carried a small saddle on which the Baron was sitting, his arms being supported by two little iron bars and his hands clinging to a wooden rod with which he steered the front wheel.

Left: Drais's hobbyhorse (1813)
Right: Penny-farthing (1874)

He propelled himself by pushing against the ground alternately with the right and left foot, almost like a skater, thus giving the vehicle a speed no less than that of a mail-coach.

He was wearing a grey top hat, a green forest official's tailcoat, green trousers, and a jabot shirt with lace cuffs. The Mannheimers roared with laughter, but he went straight through the town and on the road to Karlsruhe, which he reached some four hours later—a distance of 40 miles.

What had made the Baron conceive the idea of building such a vehicle? He started from the correct notion that a walking person uses up a great deal of energy by throwing his weight from one foot to the other. He aimed at keeping the body in the same position during the forward movement. He proved that it was quite easy to keep one's balance on a single-track vehicle, even without having one's feet on the ground, as long as the vehicle—which he called "velocipede"—was in motion.

It was copied in Paris and London. Fashionable young men appeared in the Bois de Boulogne and in Hyde Park, pushing their "hobbyhorses"—as they were called in England—along the roads. The new form of transport became a craze overnight. The Prince Regent had a special hobbyhorse built for himself and had great fun riding it in Rotten Row. Then the ladies adopted it; with their large Regency hats and flowing, long gowns they looked a little absurd on that product of the early Machine Age. Hobbyhorse riding-schools were opened in London, where toffs and fops whiled away the time. No wonder the people of the metropolis nicknamed it "dandy horse".

Baron Drais received little honour as the inventor of the velocipede; when he died in 1851 he left a whole room full of the products of his thwarted inventive genius: a meat-mincing machine, a fuel-saving stove, a typewriter—and a rusty old hobbyhorse.

After the German baron, a Scotsman took up the idea of creating a modern vehicle on the single-track principle. His name was Kirkpatrick MacMillan; he was a young blacksmith from Courthill, near Dumfries. He fixed cranks to the axle of the rear wheel of the dandy horse, and operated them with his feet by means of two long levers. Thus he could ride without ever putting his feet on the ground. After improving his model over a number of years he travelled with it from Dumfries to Glasgow in two days in 1842.

Ten years later, Philipp Heinrich Fischer, a mechanic from Schweinfurt in Bavaria, fitted pedals to the front wheels of the vehicle so that the pushing movement needed for operating MacMillan's levers was now exchanged for a continuous, rotating one.

This idea was promptly taken up by a Frenchman, Ernest Michaux, who founded the first bicycle factory in Paris. His fellow-countryman, Pierre Lallement, thought that the speed of the "bone-shaker"—as the machine was called with some justification—could be increased many times by making the front wheel with the pedals much larger than the rear wheel. Thus the "penny-farthing" was invented, which soon became extremely popular all over Europe.

A Tyre for Johnny

The era of the penny-farthing was by far the most dangerous time in the history of cycling. Getting on and off the saddle high up on top of the front wheel almost required the skill of a circus artiste.

A Swiss inventor who had settled in the Midlands, Hans Renold, and an engineer from Coventry, J. K. Starley, gave the bicycle its modern form around 1885. They called their model the "safety bicycle": with cranks and pedals in the centre between the front and back wheels, the leg power being transmitted to the rear wheel by a chain. Another Englishman, Lawson, built the first metal tube frame, which has become the standard bicycle frame all over the world—in its two forms of "gents'" and "ladies'." A Frenchman, Suviray, put the axles of the wheels on tiny steel balls, thereby reducing friction to a minimum; these ball bearings made the free-wheel action possible. Two Englishmen, Archer and Sturmey, an engineer and a newspaperman, invented the gearing of the bicycle, which enables the cyclist to ride at great speed on level roads in one gear, and to take steep hills with little effort in another.

So the modern bicycle was the combined effort of inventors from several nations. But something was still missing to make it the popular vehicle it is to-day. That gap was filled by a Scotsman who lived in Belfast, in Northern Ireland; he was a veterinary doctor, and his name was John Boyd Dunlop.

One day in 1887 the vet's ten-year-old son Johnny asked him for his help. "The boys in our school are going to have a tricycle race to-morrow," said Johnny. "I wish the thing wouldn't jolt so terribly!" Like most bicycles and tricycles at that time, it had a solid rubber tyre which gave the rider a thorough shaking. Dunlop cut two lengths from a rubber hose, glued each of them together to form a ring, and pumped air in the two rings. Then he fastened them to the rear wheels with canvas strips.

Johnny won the race by several lengths.

Later, Dunlop associated himself with a small bicycle factory to make these air-filled rubber hoses. But he improved them by using an inner tube of soft rubber to hold the air, and an outer one of thick rubber to protect it. At that time, in 1888, there were no more than 300,000 bicycles in the world; to-day there are about 75 million of them. Britain alone has 12 million; in Holland and Denmark there is one machine to every two inhabitants, and they are used alike by queens and schoolboys, by postmen and tourists—the most democratic of vehicles.

The Horseless Carriage

Three-quarters of a century after Baron Drais had raced through the streets of Mannheim with his grey top hat and his green tailcoat flying, the same town witnessed the birth of another means of transport. One day in 1886 the first horseless carriage, a flimsy-looking tricycle, invented and driven by a local engineer, Carl Benz, appeared in the streets of Mannheim—and, like the poor Baron, he reaped nothing but scorn and ridicule with his noisy, evil-smelling contraption.

In contrast to Drais, however, Carl Benz was a well-trained, experienced technician. He was the son of an engine-driver from Karlsruhe, and the owner of a small factory that made gas-motors, or internal-combustion engines, a new type of "prime mover" which he had helped to perfect. It had been his idea to build that engine into a carriage.

His motor was designed on the principle discovered by another German engineer, Dr. Nikolaus Otto, of Cologne, ten years earlier. Otto suggested the four-stroke cycle, which is still used in present-day motor-cars: the first stroke draws the gas-air mixture, prepared by the carburettor, into the cylinder; during the return stroke the piston compresses it; then it is ignited, and the exploding expanding gases drive the piston down the cylinder—this is the "working stroke"; the fourth stroke expels the waste gases. Then the whole cycle begins again. The fly-wheel momentum makes sure that a regular piston movement is maintained although only one out of four strokes does the actual work.

Not far from Mannheim, at Cannstatt, another engineer by the name of Gottlieb Daimler had made the first motor-cycle in 1885. Fifty-year-old Daimler had worked for some time in Otto's gas-motor factory, and had taken out a patent for a petrol-driven vehicle as early as 1883. His motor-cycle was an experimental machine, but he thought that such a vehicle would be very useful for the country postman.

Both Daimler and Benz began to build passenger cars. Daimler was the first to fit his cars with four-speed gears and differential gears, allowing the two back wheels to revolve at different speeds when taking a bend.

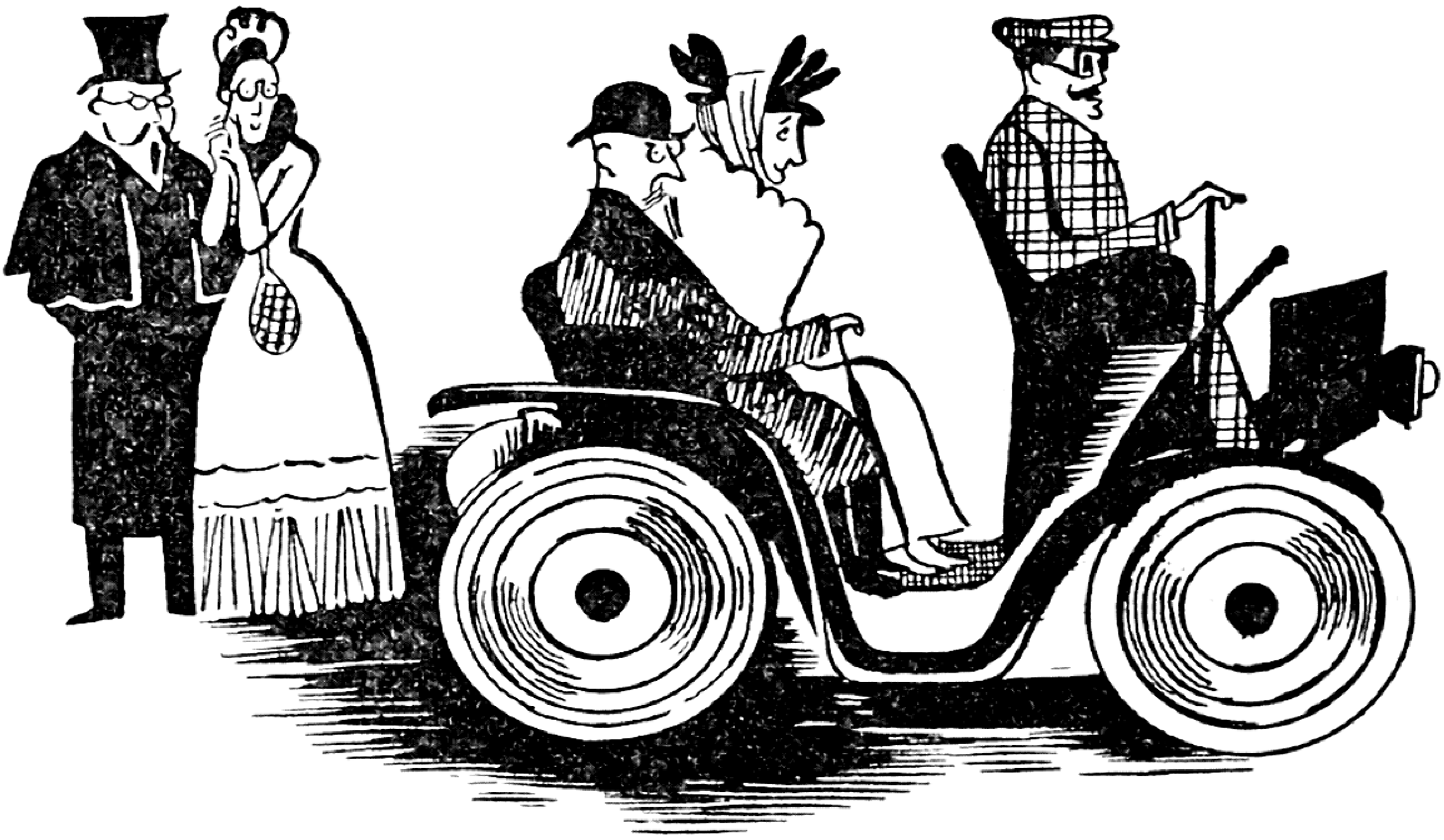
Public interest in the new vehicle was not very great at first. There was, however, one incident which was reported by many newspapers. One fine day Carl Benz went on a journey, and as soon as he had left his home his two sons, 13 and 15 years old, "borrowed" the motor-car and drove it to Pforzheim and back, 120 miles in all. It was the first genuine pleasure trip in a motor-car—although what the boys had to face on returning after many anxious hours was no pleasure, for Herr Benz gave them a thorough thrashing. Secretly, however, he was extremely gratified: the car had proved to be so reliable and practicable that it was child's play, in the literal sense, to handle it!

The Red Flag Law

France was the first country to become motor-car-minded—which she has remained to this day. Benz supplied Paris with its first taxi-cabs. Soon there were violent quarrels between drivers and coachmen, the latter fearing that their business would suffer from the new invention. France also saw the first motor races, which were quite dangerous affairs as most of the participants used them to try out their own new constructions.

Britain alone kept herself aloof from the development of the new means of transport, thanks to the ridiculous "Red Flag Law", which insisted that any carriage without horses must not go faster than 4 m.p.h. on the open road and 2 m.p.h. in built-up areas, and that a man with a red flag must march in front of any such "street locomotive" to warn the population of its approach. That law was the death sentence on any automobile.

However, a strong movement grew up among sportsmen, engineers, and Members of Parliament against the restrictive law and the Motor-car Club was formed to bring about its abolition. Success came at last in November, 1896, after sixty inglorious years of restriction. The maximum speed was raised to 14 m.p.h.



An early motor-car around 1900

The man who did more than anyone else to make the motor-car a popular vehicle was Henry Ford. Although he was not an inventor and did not contribute anything essential to engine design, that young American engineer succeeded in making the motor-car, which, around 1900, was just a toy for the rich and a sport for the enthusiasts, an everyday utility vehicle. He wanted to build cars for tough going and hard wear on all the highways and byways of his vast country; to mechanize and organize motor-car production on a vast scale, thereby increasing the output and reducing the cost to the very limits; to raise the wages of his workers so that they could be his own customers. There is no doubt that during the four decades that followed Henry Ford succeeded to an amazing degree.

It must be remembered, however, that Ford's mass production methods would have been impossible without the system of exchangeable components invented by Eli Whitney, which we have described in the previous chapter.

Within two generations, the primitive, slow, noisy, evil-smelling, and ricketty contraption of the 'nineties has changed into the elegant, fast, softly purring, streamlined car of to-day, with its individually suspended wheels, automatic gear-change, power-assisted steering, air-conditioning, and other amenities that may still be called luxuries, but will become matters of course in a few years. After all, when the self-starter was invented in 1912, making the back-breaking job of hand-cranking unnecessary, it was considered an extravagant luxury; but its introduction meant that now the "weaker sex", too, could drive motor-cars, and to-day it is a "must" in even the cheapest model.

The Strange End of Rudolf Diesel

A boy brought up by German parents in Paris, and, after the outbreak of the Franco-Prussian War of 1870, in England; who was sent all the way to Bavaria to go to school there when he was only 12—that boy could not fail to grow up to be a young man of international outlook, a man of the world able to see things beyond the frontiers of his fatherland.

Such was the background of Rudolf Diesel. After completing his studies in Munich he began to work in Switzerland as an engineer. But he did not leave his career to Chance. Ever since the day when his Professor at the Munich Polytechnic spoke about the poor efficiency of the existing steam-engines and motors in turning fuel into energy, he had been pursuing a certain idea; after that lecture he had made a note in the margin of his copy-book, just a few words reminding himself of the problem of getting more energy out of heat. That note stood over his years of study and apprenticeship like a gigantic question-mark.

The answer to it took him fourteen years to find. In 1893, he took out a patent for an economical internal combustion engine, and published a thin booklet about his invention—which, however, he had made only on paper. But on the strength of that booklet, big engineering firms in Germany, including Krupp's, offered him facilities to build that engine, and after four years' work it was ready on the test stand of his Augsburg laboratory—the first Diesel-engine.

The basic new idea was that this machine, although operating in a similar way to the petrol-engine, could use heavy oil, that is, crude, unrefined, and therefore cheap petroleum, as compared with the refined, expensive petrol which the ordinary petrol-engine needs. The Diesel engine works without an ignition device, which makes its operation simpler and reduces its construction costs. The piston draws air into the cylinder, compresses it up to 35 atmospheres pressure and thus heats it up to 500° Centigrade; into this hot, compressed air a small dose of liquid fuel is injected—and the heat makes it at once explode. This drives the piston down the cylinder, but all through the "working stroke" more oil is injected so that the continuing explosion keeps up the pressure in the cylinder until the piston has reached the bottom of the cylinder. The fourth stroke, as in the petrol-engine, expels the waste gases. The result is that in this engine no less than 35% of the heat created is transformed into energy; the petrol-engine transforms only 28% and the steam-engine a mere 12%.

The Diesel-engine was greeted with enthusiasm everywhere, and before long it was adapted for a variety of purposes: as a stationary "prime mover", in trains, ships, lorries, buses, submarines, and airships. Diesel founded a world-wide company with headquarters in Munich, and great sums of money began to flow into his pockets. He seemed to be one of the very few inventors to reap the full benefit from his work.

All the greater, therefore, was the sensation created by the unbelievable news that one night in September, 1913, Rudolf Diesel had vanished from a cross-Channel steamer on his way to England!

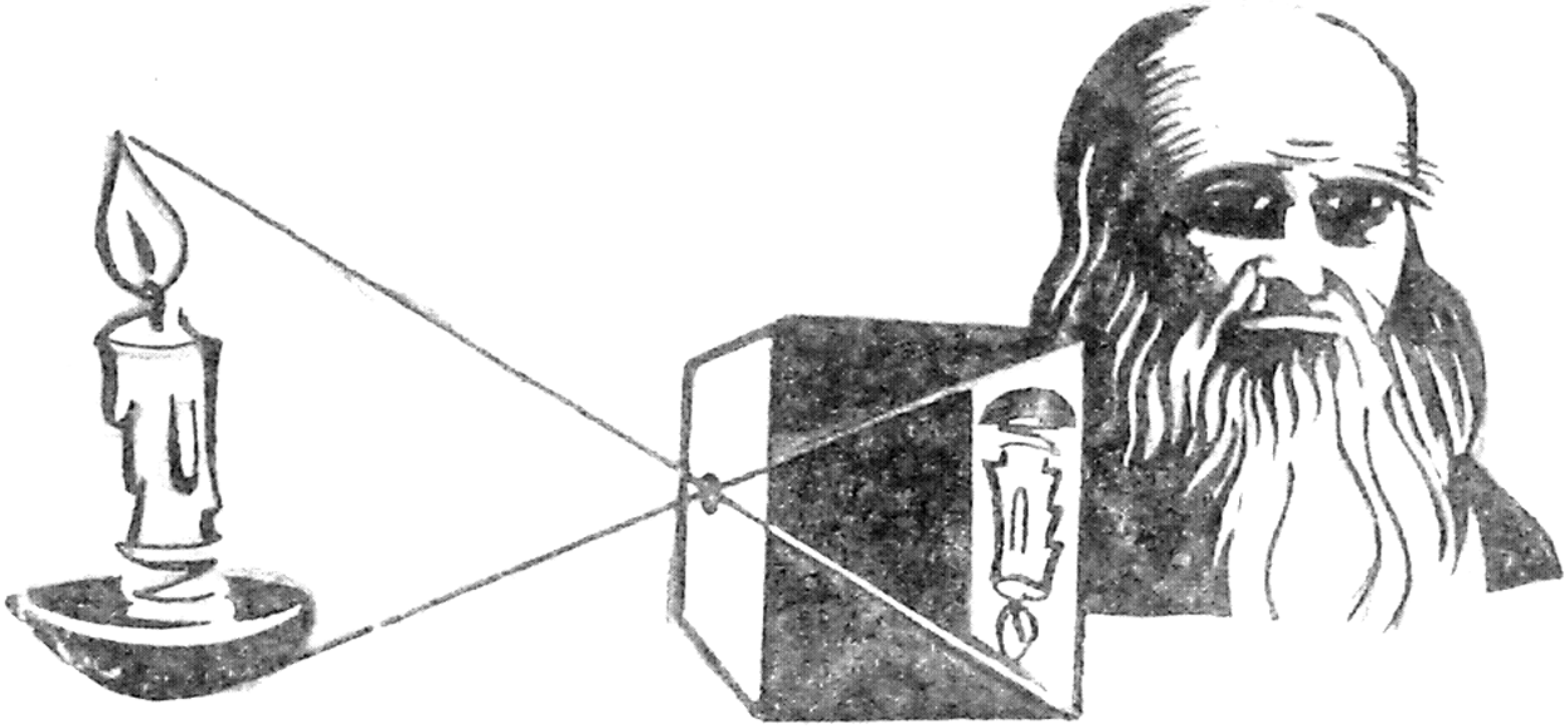
First there were some fantastic rumours, but then the truth became known.

His financial situation had become desperate. He had spent more than he could afford, patent suits had eaten into his fortune, and he had embarked on all kinds of risky speculations.

He was a bad businessman. Others might have easily found a way out of the financial dilemma; he saw only the end of his career, the ignominy that was awaiting a bankrupt. And he had decided to take the step which appeared to him the only solution to his problems.

His body was found in the sea. His two sons identified the things in the pockets as his. Among them was a diary. It had a little pencilled cross marked against that fateful day in September, 1913.

Rudolf Diesel has gone; but the Diesel-engine has come to stay. It has been adapted to drive electric trains, without electricity from stationary power stations, but generating their own current in the locomotive. The future will bring the widespread adaptation of the Diesel-engine for ordinary motor-cars, which have so far been the exclusive domain of the petrol-engine.



Leonardo's camera obscura

Chapter Six

PICTURES

The magic lantern was invented by a German Jesuit, Anastasius Kircher, in the seventeenth century, but it was not until the Victorian age that it was widely used in the homes and lecture halls.

This was the first of the three elements which had to be combined to form the most popular entertainment of our own days—the cinema.

The Secret of the Old Cupboard

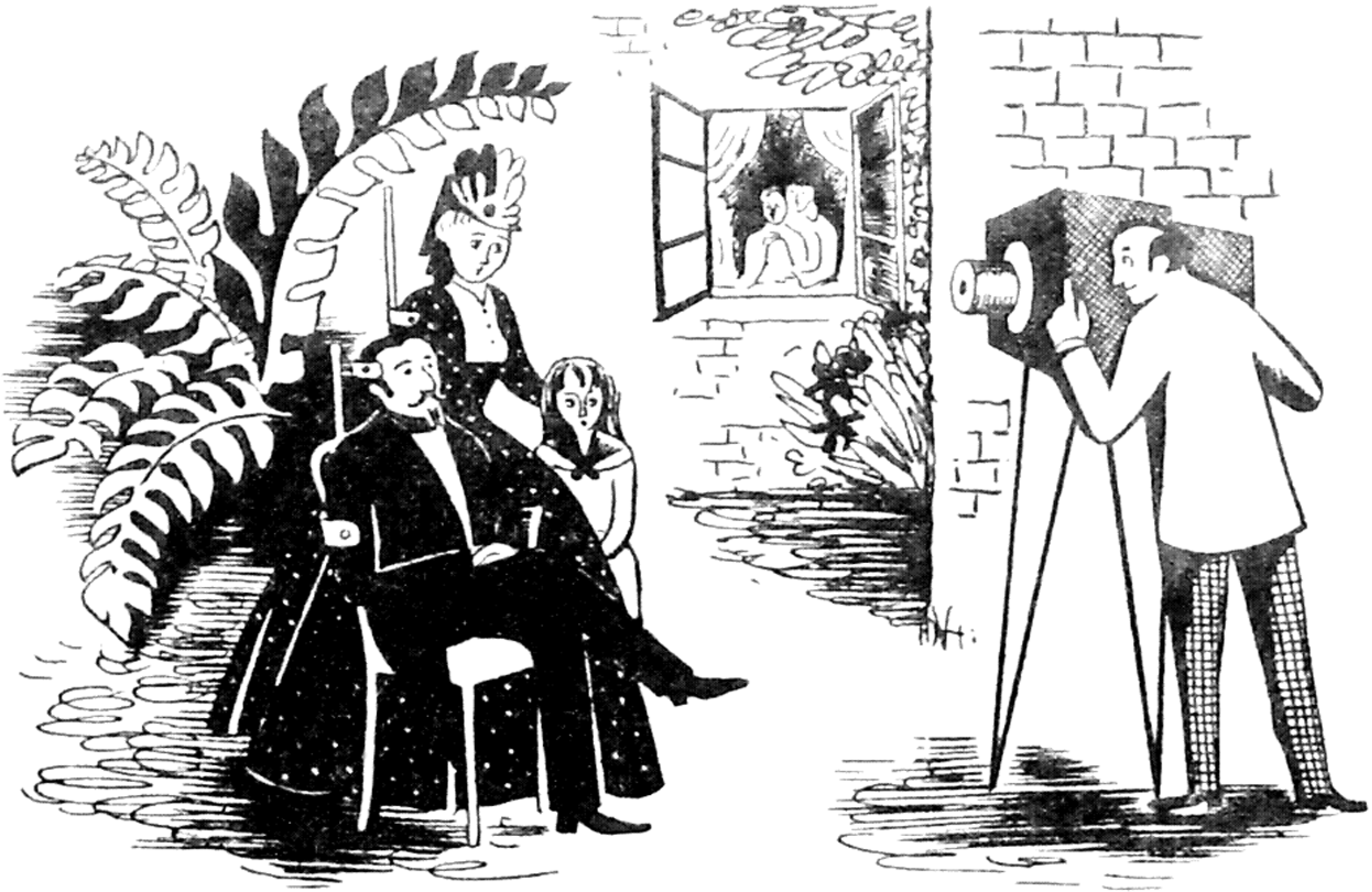
The second element was the mechanical and chemical recording of what we see. Among the many things which that Italian genius, Leonardo da Vinci, invented was the "camera obscura": a box with a small hole in one side into which the light rays penetrate, throwing on the opposite wall the upside-down picture of objects outside the box. Leonardo lived around 1500, and there was no prospect of inventing something that would preserve the pictures thrown on the wall of the dark box. Chemistry in our modern sense did not exist, and the alchemists were mainly concerned with trying to find the "philosopher's stone" and to manufacture gold.

Three hundred years later, a retired French officer, Nicéphore Nièpce, who had fought under Napoleon, began to make experiments with chemical substances which could be influenced by the sun's rays. He started with Leonardo's camera obscura. He fitted a lens into the little hole so that he could get a clearer picture of the objects by bringing them into focus.

Then he began to search for a sensitive material on which the light rays could make a permanent impression. It was not such a fantastic idea; after all, the sunlight tans our skin, it bleaches fabrics, and helps to give the flowers their beautiful tints. After numerous experiments he became convinced that what he was looking for was asphalt; for if part of a piece of asphalt was exposed to the sun for a long time that part became insoluble in vegetable oils. It was a lengthy job, and only after days of exposure did anything like the contours of a picture appear on Nièpce's asphalt plate in the camera.

Meanwhile, an English chemist was working along the same lines: Thomas Wedgwood, the son of Josiah, famed for his beautiful porcelain. He collaborated with Humphry Davy at the Royal Institution in London, trying to produce shadow pictures on paper soaked in silver nitrate. When he laid some plant leaves on it the part of the paper which was not covered became black after being exposed to the sunlight, while the portion under the leaves remained white.

After nearly twenty years of work, Chance brought Nièpce into contact with another man whose mind was occupied by the same problem. His name was Louis Jacques Mandé Daguerre, and he was a decorator and diorama showman. He discovered that silver nitrate is a light-sensitive material, much more so than asphalt. Nièpce, on the other hand, had built a nice camera: a quadrangular box, six inches long, with a lens fitted in a tube which could be telescoped for focusing. But he was now an old man, and before the two inventors could obtain more than some weak, shadowy pictures he died at the age of 89.



Early photography

Daguerre worked on. Four more years passed; then, in the autumn of 1837, Chance stepped in again to reward his perseverance.

He had put a few spoiled plates, which he thought had not been exposed long enough, in a cupboard with the intention of washing them and using them again. After some weeks he took them out—and could hardly believe his own eyes: there were beautifully clear pictures on the plates, more lifelike than he had dreamed his pictures would ever be!

At once Daguerre was seized by a kind of inventor's fury. He scrutinized every nook and corner with a magnifying glass. The cupboard seemed completely empty. But it wasn't. At last he discovered, in the narrow fissures at the bottom of the cupboard, a few tiny, glittering balls of mercury, which had run out of a broken bottle.

The Daguerreotype Craze

So that was the solution! The silver nitrate plates had been "developed" by mercury vapour. He put his theory to the test, exposed a plate, and held it over a bowl with heated mercury in a dark room. Magically the picture appeared on the plate. He fixed it by dissolving the silver haloids on the plate in a bath of sodium sulphate. The first photographic process was born, the Daguerreotype.

Its public success surpassed all his expectations. All Paris scrambled to be daguerreotyped. To sit for an hour in the pitiless sun, and then to take home one's portrait, darkly visible on a small medallion—that was the latest craze. Artists who feared for their livelihood in the face of the new rival hastened to buy cameras from Daguerre, and to switch over from painting to daguerreotyping. That was the reason why many of these early photographs reveal such fine artistic taste.

When Daguerre died in 1851, a new photographic system had already begun to supersede the daguerreotype, which produced pictures only in one copy that could not be duplicated or enlarged.

An Englishman, Fox Talbot, had the idea of splitting-up the process into making negative pictures and printing positive ones from them. He used paper for both negatives and positives; some of his "calotypes", as he called them, are of great artistic beauty.

Next came Nièpce de Saint Victor, a nephew of the man who worked with Daguerre, who introduced glass plates for the negative pictures in 1847. These plates, however, were coated with a wet solution and therefore rather difficult to handle; yet for many years, photographers in Europe and America used them extensively, and some very interesting historical records were made with them—although the photographers had to carry with them an enormous amount of equipment, including a tent for immediate developing of the wet plates.

Micro-photography for sending secret messages was invented by some ingenious Frenchmen during the siege of Paris in 1871. They reduced written messages to very small size by photographic means, and printed them on thin collodion sheets which were taken out of the beleaguered city into unoccupied France by carrier-pigeons.

At last, in the 1870s, the English inventors Maddox and Joseph Wilson Swan succeeded in producing a dry coating for photographic plates, and with this step the greatest obstacle to the further progress of photography was eliminated.

But an entirely new development began in 1887. Two Americans, Goodwin and Eastman, announced the invention of a new photographic material, the celluloid film, which had obvious advantages over the fragile, heavy glass plate. At the beginning of our century, cheap cameras for amateurs, operating with the new material, began to appear in the shops. Little by little the size of the negatives became smaller while the lenses grew better in power and definition, and the chemical layer on the celluloid film more sensitive to light and colour.

The Man Who Stared into the Sun

We said at the beginning of this chapter that three elements had to come together to make the cinema possible. One was the magic lantern, the second the photographic camera; the third was a scientific discovery.

The pleasures which the film offers to our eyes have been paid for with the loss of sight of a man whose name is hardly known outside the annals of science: Joseph Plateau, a Belgian professor, born in Brussels in 1801.

He studied the mechanism of sight, beginning a series of most dangerous experiments at the age of 28 by staring into the sun for 25 seconds to see what the effect on his eyes would be. He was blind for nearly a month. But he went on experimenting, increasing the length of time during which he looked into the sun, knowing that in the end this would cost him his sight. He walked into eternal darkness as one of the great heroes of science. At the age of 42 he was completely and incurably blind; the sun had destroyed the retina of his eyes. But he continued to work as well as he could until he died at the age of 82.

Science profited enormously from his research. He studied the so-called inertia of the eye, which makes a picture remain on the retina for about one-sixth of a second after it has disappeared from our vision. That means that if we see a succession of individual pictures, each of which appears only for a fraction of a second, they "overlap" one another in our brain, and if they show consecutive phases of movement that movement will appear to us continuous.

Sir John Herschel used this discovery to make a simple toy: a cardboard disc with a bird on one side and a cage on the other. By turning it rapidly on a pair of strings one could see the bird sitting in the cage!

So the third element, the scientific principle of cinematography, had been established—the basis of that invention which consists, roughly speaking, of dividing up a scene in motion into individual pictures by means of a camera, and putting it together again by projecting the pictures with a kind of magic lantern. If our eyes could not do the rest—that is, make these pictures merge into one another—cinematography would be impossible.

One day in 1872, Mr. Edward Muybridge of Kingston-on-Thames, who had made his name as a first-class photographer in America, was asked by the Governor of California to settle a dispute which the Governor was having with some friends: whether a galloping horse did or did not lift all four feet off the ground at one point of its gallop. Muybridge put up 24 cameras in a row on the racecourse of Palo Alto, attaching a thread to each of the shutters. As the horse galloped along the track it broke one thread after the other, thus operating the shutters. The experiment, though somewhat costly for the Governor, was a complete success; and it showed that a galloping horse does, in fact, lift all its feet in the air for the fraction of a second.

Muybridge published his pictures in a book, *The Horse in Motion*, which created a sensation among all those who were experimenting with photography of motion.

In 1874, a German by the name of Janssen invented a primitive motion-picture camera which he called "photographic revolver"; it took a dozen pictures at short intervals. Next came a Frenchman, Professor Marey, who turned Janssen's instrument into a "photographic gun", with a revolving disk for taking the negative pictures. He used it exclusively for scientific purposes, especially in order to analyse the movements of men, animals, and birds. He also built a simple projector so that he could show the pictures to his students at various speeds.

An Inventor Disappeared

An English photographer, William Friese-Greene from Bristol, experimented with moving pictures a few years before Eastman marketed his film. He used glass plates and even paper strips soaked in castor oil to make them transparent. Then he had the same idea as Eastman—to use celluloid coated with a sensitive layer. He was not a technician; so he had to have his camera and projector built by a firm of instrument-makers, and soon got into debt because the equipment did not work well enough to attract a financial backer. However, he patented his invention in 1889, and went out into Hyde Park to shoot a few feet of film.

That night, in his workshop, he developed and printed the film and let it run through the projector. And the miracle happened: there were the people and the coaches and horses, all moving nearly as in real life! He was so excited that he had to share his experience with some human being. Although it was midnight, he rushed into the street and dragged a suspicious policeman into his workshop to witness the miracle.

But Friese-Greene was not a good businessman, nor did he have sufficient stamina to stick to his guns. When he found himself in difficulties with unpaid bills arriving by every mail, he pawned his patent, and never bothered to renew it. He died penniless in 1921.

Perhaps the strangest case is that of Augustin Le Prince, a French artist and inventor who had settled in Leeds. During a visit to New York he happened to see Muybridge's book, *The Horse in Motion*, and was so fascinated by the idea of photographing motion that he built a camera for use with film, and tried it out by shooting the traffic on the bridge in Leeds in 1888. Before showing his invention to the world he wanted to get the advice of his brother, who lived in Dijon. On the morning of September

16, 1890, Le Prince boarded the train from Dijon to Paris after visiting his brother. From that moment there is no trace of him, nor of his many pieces of luggage, which must have contained the drawings of his camera and projector. Although the search for Le Prince was continued for more than a score of years, no clue was ever found. His wife was convinced that he had been kidnapped by other inventors who feared that he would get ahead of them and reap the rich harvest which the invention of cinematography was bound to bring.

Edison, too, was among the cinema inventors. Curiously enough, he did not construct a camera for taking motion pictures, nor a projector; he took individual pictures on glass plates, his first shot consisting of 158 photographs depicting a love scene which was acted by two of his employees at Menlo Park. These pictures were printed on a film band, and made to run off in Edison's new invention, the "kinetoscope", a penny-in-the-slot peep-show for the fun arcades.

In 1894, five years after its introduction, two Greek showmen asked an instrument-maker in London, Robert W. Paul, to build a number of these machines for them as the one they had brought from the States was doing roaring business in a shop near Liverpool Street Station.

But Paul thought that it would be a better idea to show these moving pictures to a whole audience instead of just one person at a time. He built a projector, and went on to design a camera. Then he built a little studio in New Southgate, a northern London suburb, to shoot his own films.

On February 20, 1896, Paul showed his moving pictures for the first time to an audience at Finsbury College.

He was the first to make "feature" pictures in England. He also took the first newsreel picture—of the Derby of 1896; and the Prince of Wales was invited to see his horse win a second time, namely, on the music-hall screen on the evening of the race. He attended and was delighted.

Robert W. Paul was Britain's first film industrialist. But suddenly one day in 1910 he put an end to his career in the new medium in a spectacular fashion. He made a large heap of his entire film stock, worth a fortune, and lit it with a match.

Perhaps he was disgusted with the bad taste which the first cinema audiences were showing; perhaps he did not believe that the film would ever be anything but cheap entertainment for the uneducated.

Panic at the Polytechnic

A former American Treasury stenographer, C. Francis Jenkins, and two German showmen, the brothers Skladanowsky, were among the inventors who built cameras and projectors and made films in the early 1890s. But in all fairness we must admit that no one has a better case in claiming to have invented cinematography than Louis and Auguste Lumière, two brothers from Lyons in France who owned a factory for photographic equipment.

They talked together about the possibility of converting Edison's kinetoscope into a projecting machine so that a whole audience could see the films and not just one person. Then one night, Louis, unable to sleep, turned the problem over in his mind to such good purpose that in the morning he told his brother the solution he had arrived at. They went to work at once, and on March 22, 1895, were able to show their first film—a shot lasting only for a few seconds, showing workers leaving the Lumière factory for their lunch break—to a group of businessmen in Paris. It made a great impression. But it took the brothers another nine months to produce sufficient films suitable to show to a larger audience. Thus, on December 28, 1895, the first cinema in the world was opened in the basement of the Grand Café in the Boulevard des Capucines, Paris. The programme consisted of a dozen brief films lasting altogether 20 minutes; among them was a funny family scene, "Baby's Supper", "A Boat in the Surf", "Demolition of a Wall", a scene showing a boy teasing a gardener by stepping on his hose and getting splashed for it, and "The Arrival of a Train in a Station".

There were queues at the box-office from morning till night.

After Paris, London was given the treat of its first public film show. On that very day, February 20, 1896, when Robert W. Paul showed his films at Finsbury, the Lumières' "Wonderful Living Pictures" had their first public performance in London at the Polytechnic in Regent Street. It was the same programme as that shown in Paris, and just as in Paris the "Arrival of a Train" was the greatest sensation. When the audience saw the railway engine coming straight towards them there were always people who panicked—men jumped up and rushed for the exit, ladies fainted. After the first performance the management engaged a nurse to deal with the casualties.

The Lumières' films are still in existence and can be shown by any modern projector, for the width of the film and the arrangement of the sprocket holes for moving it through the projector and camera have remained the same ever since: a good reason for regarding the French brothers as the true inventors of the cinema as we know it to-day.

It has, of course, made great strides since 1895. After remaining silent for the first 34 years of its existence the film learnt to speak, to sing, and to produce all the noises we know in real life. Ever since its introduction the cinema tried to become more and more lifelike, and sound was the most important achievement at which the inventors aimed.

There were many attempts to give the film a voice. Edison had connected his kinetoscope to the phonograph, but the arrangement was too primitive. Then came a number of inventors who tried to combine the gramophone with the film, but the difficulty was the accurate synchronization of sound and picture so that the words would come out of the actors' mouths while their lips were forming them.

Sound, Colour, and Depth

The practical solution of the problem of the sound film came from the scientific laboratory. Around 1900, the German physicist, Ernst Ruhmer, succeeded in recording sound waves by photography, but only for the purpose of analysing them. In 1906, however, the English engineer, Eugene A. Lauste, took out a patent for the simultaneous recording of picture and sound on the same film. He used one half of the film width for the picture and the other half for the sound. The question to which he could not find the answer was how the "sound track" could be changed back into sound. After Lauste had spent half a million pounds on his experiments and ruined his health he abandoned them, convinced that his idea was no good.

Yet he was on the right track, although more than twenty years of electrical and electronic development had to pass before the sound film could become a fact. The amplifier valve had to be invented, efficient loudspeakers and microphones designed, and a number of precision instruments built; for the recording and reproduction of sound-on-film is a complicated process.

In principle, the matter is quite simple: a microphone, which turns every sound into electric impulses, is connected with a small electric lamp which increases or decreases its light according to the rhythm of those impulses, and the oscillations of the lamp are photographed on a film band passing it. Then a positive print of the film is made, or rather of the narrow "track" along the edge of the film, on which the varying intensity of the light has been recorded; this is combined with the picture film so that both are, as the technicians call it, "married"—which prevents either of them from running ahead of the other.

When the film runs through the projector—at the constant speed of 24 pictures per second—the sound track passes through a special little box with a small but strong lamp of continuous intensity. It shines through the transparent sound track, and falls on a photo-electric cell. This cell modulates an electric current passing through it according to the brighter or dimmer light it receives through the sound track, because its electric resistance varies with the varying amount of light it receives. This modulated current is amplified and goes into the loudspeaker, which transforms it back into sound.

The first picture made with sound-on-film was *The Jazz Singer*, with Al Jolson in the leading part in 1928. It was a sensational success; the age of the silent film had come to an end. The whole structure of the film business changed completely within a few years. Producing and showing films grew much more expensive because so much additional equipment was needed; many of the little "flea-pit" cinemas disappeared and made way for the luxurious picture palace; the films became an enormous industry, playing an increasing part in the economic and social life of every country.

Colour was another problem which interested inventors right from the beginning of the cinema. Friese-Greene had early developed a colour film system, but colour cinematography began in earnest when three scientists—D. F. Comstock, H. T. Kalmus, and W. B. Westcott—took up the problem at the Massachusetts Institute of Technology, Boston, in 1913.

Twenty years later, the first film in Technicolor—that was the name the three inventors gave their system—was shown in the cinemas: a Walt Disney cartoon, "Flowers and Trees"; and although it is by no means a simple or cheap colour system, it has been popular with film-makers ever since.

Technicolor needs a special camera. The beam of light entering the lens is split by a half-transparent gold mirror, and distributed into two "gates" arranged at right angles from each other. In one of the gates a bipack film—two films running together—is exposed, in the other gate a single film. In front of the bipack film is a magenta filter; the front film records the blue elements of the light beam, and carries a red filter in contact with the rear film, which records only the green elements. In the second gate, behind a green filter, runs a film recording only the red elements.

A matrix is made of each of the three negatives—a relief film in gelatine. These matrices are dyed in their complementary colours; the blue film in yellow, the red film in green, the green film in red. A fourth film, the so-called key picture, is made in black and white from these three films. Then, in four consecutive processes, all the four pictures are printed on a single film, which now contains all the colours.

A good system using normal cameras and only one film was developed in Germany during the second World War; it operates with four very thin layers: blue, green, and red, with a yellow filter layer between the first two. The developing is done in the complementary colours. Russians as well as Americans adopted this system after the war and developed it.

After sound and colour, depth—the stereoscopic effect

—has been the film inventors' problem child for a long time. We have two eyes, and the difference between the "points of view" of the eyes makes us see "in space".

Stereoscopic viewing is an old invention. Even before photography was invented, Sir Charles Wheatstone built the first stereoscope, which became a favourite toy in Victorian days. It is a viewing apparatus with two eyepieces. Two pictures of the same scene, one seen from the viewpoint of the right eye and the other from that of the left, are put side by side into the viewer—and when we look at them through the eyepieces they combine into one three-dimensional picture.

3-*D and Stereo-Sound*

But you cannot project two pictures side by side on the screen and make the cinemagoer look at each of them with one eye only; that is obviously impossible. One way is to project the two pictures, which have been photographed from the viewpoints of the right and left eye respectively, on top of each other on the screen, one tinted in red and the other in green; the spectator looks at them through glasses which are tinted red for one eye and green for the other: thus the "red eye" cannot see the red picture but only the green one, and the "green eye" only the red one. This system was tried out in the cinemas dozens of years ago. It has the disadvantage of excluding colour films.

In 1938, an American inventor had the idea of separating the two pictures not by the red and green colours but by polarized lenses. Normally, the light rays vibrate in an infinite number of "planes" at right angles to the path of the light. By using certain kinds of lenses the projected picture can be confined to only one "plane". In this system, the two pictures, projected on top of each other on the screen, are each polarized in a different plane; the spectator looks at them through glasses which are correspondingly polarized for each eye. The effect is that each eye sees only the light plane of one picture. The system takes away something of the brilliance of the film picture, but makes it possible to project colour films.

This, then, is the present "3-D" system, which has been much improved and perfected by two young British inventors, Raymond and Nigel Spottiswoode. Other innovations using enormous, round screens cannot show pictures in depth; the screen remains two-dimensional. A stereoscopic system invented by a Russian engineer, Semyon Ivanov, operates without glasses; the screen is studded with very small conical lenses which reflect the two projected pictures so that the spectator, after wriggling in his seat to find the right position, combines them into one stereoscopic picture. But it is an expensive system and works only in rather small cinemas.

Hand in hand with the 3-D pictures goes often stereoscopic sound. The sound track can be split up into four or five "channels", each of which operates another loudspeaker: thus, music or noises can be made to come from either side, the front or the back of the audience, or to travel across the cinema according to the film scene.

The cinema tries, as we see, to become as natural as life itself. But try as it may, it will never be as "natural" as the theatre.

Chapter Seven

MEN WITH WINGS

MANKIND's oldest dream is that of flying; and none seemed more absurd. The Greek legend of Daedalus and Icarus tells of that immemorial longing. But again and again, men were told by their teachers and philosophers that it could never be fulfilled.

Inventors are dreamers. They take no notice of warnings and ridicule. Their field is the "impossible". Leonardo da Vinci was such a dreamer. He sought a technical solution of the problem of human flight, and made models of a machine that would, he thought, enable men to fly like birds with artificial wings. Like Leonardo, many of the pioneers of human flight believed that all they had to do was to imitate birds. If these creatures, all heavier than air, could fly, why should not men fly in the same way? Quite a number of these experiments in the course of the centuries ended abruptly with the experimenters breaking their necks or becoming the laughing-stocks of their fellow-men by attempting to play the bird.

The First Balloon Ascent

On a cold day in January, 1783, Joseph Montgolfier, who, with his brother Etienne, owned a paper factory near Lyons in France, was travelling in the mail-coach on his way to Avignon. He looked out of the window at the clouds sailing effortlessly in the sky. Why could not men fly, he asked himself, and conquer distance as easily as a cloud? And what *was* a cloud? Was it something like smoke?

Late that night in Avignon, when he went to his room at the inn, he ordered a piece of taffeta with his supper. An hour later a smell of burning came from his room. At once the landlord rushed in to see if there was a fire, but Joseph smiled reassuringly and asked him to watch an experiment. He had made a cube out of the taffeta, open at the bottom. Then he put some old newspapers in a vessel usually kept under the bed, lit them, and held the cube over the fire: and immediately, as though lifted by an invisible hand, the cube began to rise, floating towards the ceiling, borne up by the hot air. . . .

The landlord fled from his uncanny guest's room, and two minutes later the porter came up and asked Joseph to leave at once. But Joseph did not mind at all. He had solved his great problem.

Back in Annonay, he repeated the experiment before his brother, Etienne, who was thrilled by it, and on June 5, 1783, they invited all the inhabitants of Annonay to witness the magic spectacle of a flight through the air. They had built a scaffold with a large round grate, and placed an empty sack of paper-lined linen above it. A fire was lit, and the sack began to fill with the rising smoke; it had to be held on eight ropes by strong workers from the Montgolfier factory. Then Etienne commanded, "Let go!"—and the sack rose quickly, floating up over the roofs of the town until it was no more than a speck in the sky. The people of Annonay, crazy with excitement, ran after it as it went before the wind. They found it lying in a field a mile and a quarter away—merely a limp, empty sack again.

The story of the "electrical smoke", or "Montgolfier

Air", as the people called the mysterious force that had lifted the sack, reached Paris and created great curiosity. A committee of scientists in conjunction with the authorities invited the brothers to repeat their feat in the metropolis. They agreed to build a new, large balloon for the occasion; but the Parisians were so impatient to see the new miracle that they did not want to wait for the inventors from Annonay. Money was collected, and a noted scientist, Professor Charles, commissioned to build such a contraption with the help of the brothers Robert, well-known manufacturers of technical apparatus.

Professor Charles studied the reports from Annonay, but could not discover what that "electrical smoke" was. However, his scientific reputation was at stake, and he did not dare to let anybody know that he had not the faintest idea how that sack was made to fly. Perhaps the "Montgolfier Air, half the weight of common air", which the reports mentioned, was hydrogen, a gas much lighter than air? It had been discovered by the English scientist, Cavendish, in 1766.

So Charles went ahead with his own balloon. It was made of silk and coated with a rubber solution to prevent the gas escaping. The brothers Robert also produced the hydrogen, 1,000 cubic feet of it, from iron filings and sulphuric acid—a method which was so dangerous that they could have easily been blown up. But all went well, and on August 26, 1783, 300,000 Parisians assembled on the Champs de Mars to see the first hydrogen balloon, unmanned, of course, rise in the air.

It came down fifteen miles away at the village of Gonesse. The hydrogen, mixed with some sulphuric acid, had, of course, dispersed, and the good people of Gonesse were convinced that the thing that had dropped in the field, spreading a Satanic smell of sulphur, was none other than the devil himself. So they turned out in force, armed with dungforks, flails and stones, to make an end of Old Nick for good.

Etienne Montgolfier had come secretly to Paris, and had watched the ascent of the rival balloon. Later, he made a report to the Academy saying that hydrogen was much too dangerous a gas for use in balloons, and that his own system, using hot air, was much safer.

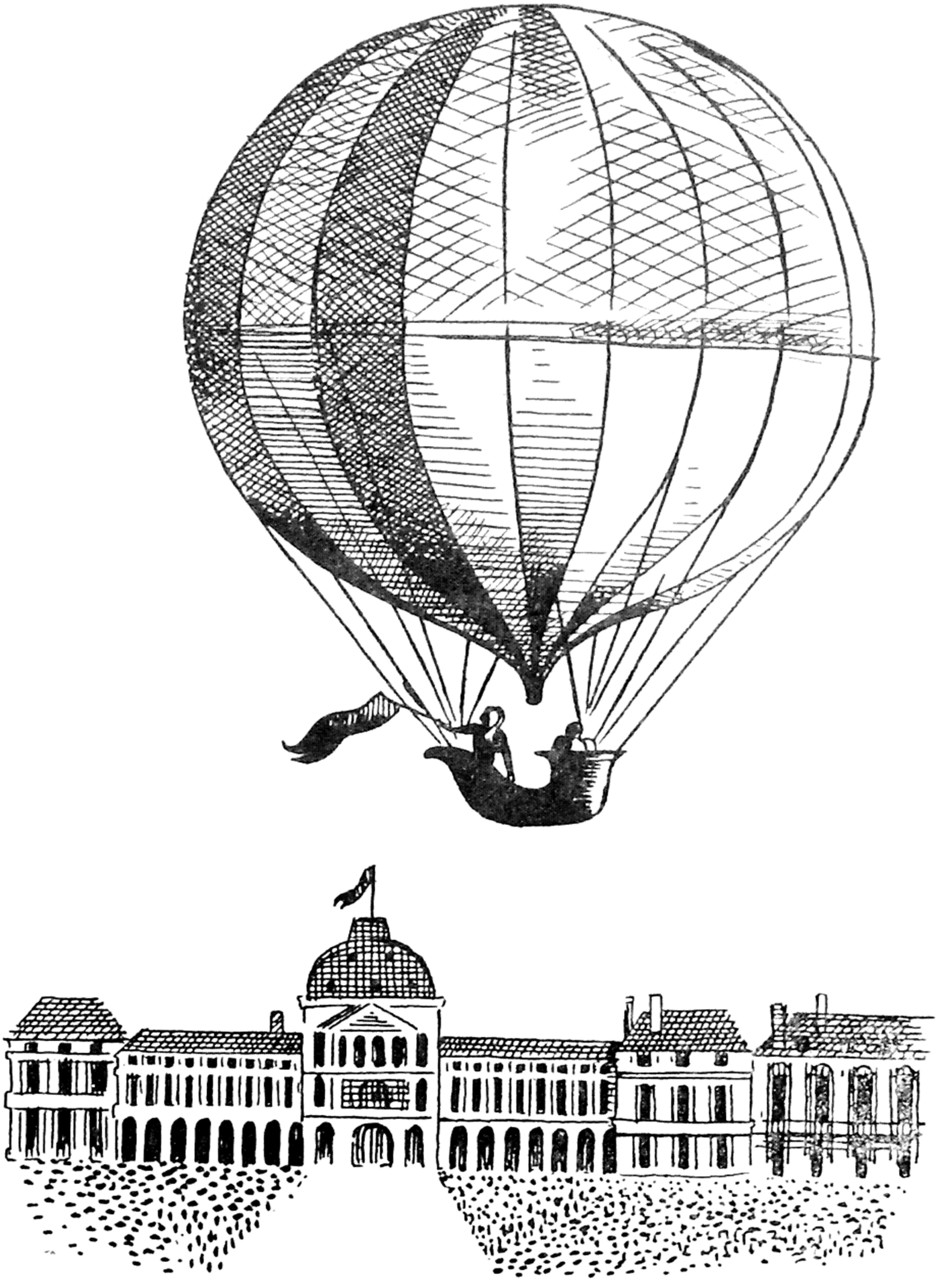
The experts split into two camps, one advocating "Montgolfières", hot air balloons, and the other "Charlières", hydrogen balloons.

Up to now, the balloons, of course, had carried no passengers. Who was to be the first human being to fly? King Louis XVI decided that in view of the great danger the first aeronauts should be two criminals who had been sentenced to death. But a young nobleman, Pilâtre de Rozier, implored the King to let him be the first airman, and not a couple of murderers. At length the King consented and Rozier with a friend, the Comte d'Arlandes, instructed by the Montgolfiers in the handling of the balloon, took off on November 21 of that great first year of flying, 1783, in a balloon which carried its own fire in the gondola.

They flew for five miles at a moderate height, and then put out the fire and made a slow and safe descent.

How to Steer a Balloon

All Europe was enthusiastic about the great achievement. The Montgolfiers were acclaimed as national heroes, but in the history of flying Professor Charles played an even greater part. He designed a safety valve and control mechanism for his hydrogen balloon; he threw a net over it and suspended the gondola from this so that its weight was evenly distributed. He also fitted the gondola with measuring instruments, such as a thermometer and a barometer, and made an anchor for the



Professor Charles's hydrogen-filled balloon (1783) balloon to facilitate the landing. With his new, improved balloon he undertook his first passenger flight, with himself and one of the Robert brothers in the gondola, on December 1, 1783—after a dramatic dispute with the King who sent a police officer to prohibit the flight because of the dangerous nature of the hydrogen. Only after Charles had threatened to kill himself and take the secret of balloon-building with him to the grave did the King grant permission to start.

This flight was of the greatest importance for the development of air travel. The balloon remained in the air for two hours, and then made a perfect landing—but only to allow Charles's passenger to alight. For Charles was bent on an enterprise for which he alone could bear the responsibility: the first high-altitude flight.

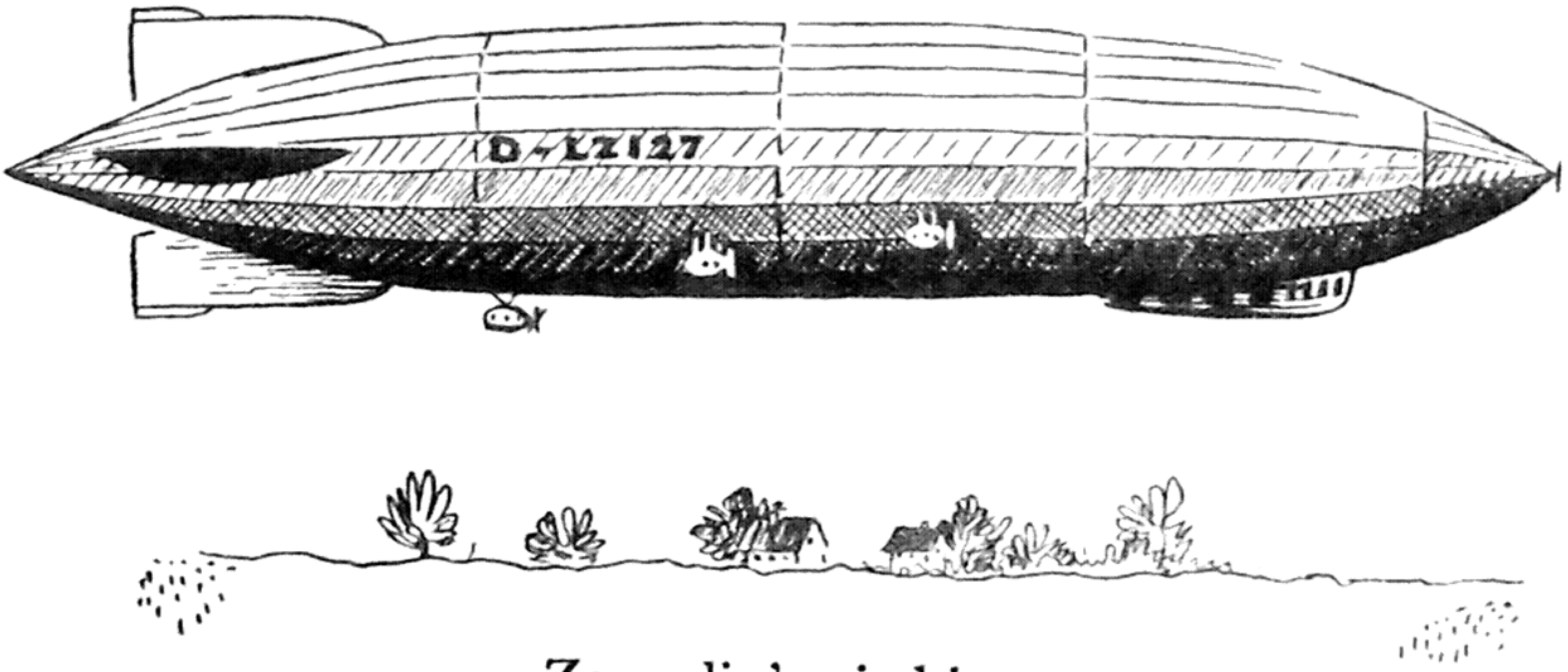
Entranced with the fascination of flying, of escape from gravity, he allowed the balloon to rise higher and still higher: to the fantastic altitude of 10,000 feet! Then severe pain in the ears compelled him to return to the earth by letting out the hydrogen. He landed safely.

"Ballooning"—with hydrogen, for the hot-air system of the Montgolfiers proved too primitive and awkward—became a craze all over Europe. The Straits of Dover were first flown in 1785 by a Frenchman and an Englishman. Soon after, Rozier crashed—the first of a long line of victims of flight. Etienne Montgolfier died peacefully in 1799, Joseph in 1810, while Professor Charles lived until 1823.

All through the nineteenth century, inventors tried to build balloons which could be steered like ships. It was left to a German officer, Count Zeppelin, to design the first reliable dirigible airships around 1900 by fitting them with the newly-invented petrol- and Diesel-engines, and by making them enormously long—several hundred feet. In the first World War, the Germans bombed England from these airships, but their losses were very heavy indeed; for these droning, cigar-shaped monsters, gliding slowly out of the clouds and into the searchlight beams, were an extremely easy and vulnerable target for the anti-aircraft guns.

It was, however, not a Zeppelin but a British airship, the R.34, which crossed the Atlantic for the first time in July, 1919, making the trip with a crew of 30 from Scotland to Long Island in 108 hours.

Seventeen years later, a single event put a stop to any further development of the airship as a means of transport.



Zeppelin's airship

Germany's biggest Zeppelin, the Hindenburg, which had carried out many transatlantic passenger flights, exploded as it tried to land at Lakehurst, with great loss of life. The Montgolfiers' warning that hydrogen was too dangerous for filling airships had come horribly true. The Hindenburg could have been filled with the safe light gas, helium, but Germany, already preparing for war under Hitler, would have had to buy it from abroad and preferred to use its limited foreign currency for raw materials for armaments. The safety of the Zeppelin passengers was disregarded, and so the development of lighter-than-air transport came to an end.

Two More Pairs of Brothers

Man had learnt to fly with balloons; yet he went on dreaming of imitating his fellow-creatures, the birds, which need no gas lighter than air to carry them skywards. How did they do it?

An English scientist, Sir George Cayley, was the first to carry out a modern study of this question. As a boy of ten he had already attempted to fly with a home-made machine; and in 1799, when 26, he engraved on a small silver plate a diagram of forces involved in birds' flight; and on the reverse side he depicted what in his opinion a glider aircraft should look like. This little silver plate, signed "G.C. 1799", is now in the Science Museum, South Kensington. Ten years later, he wrote a long article about the possibility of building heavier-than-air machines in which he said that they must have rigid wings, and fly like a gliding bird. "I feel perfectly confident," he wrote in this prophetic article of nearly a hundred years before mechanical flight became a reality, "that it will be possible to transport persons and goods more securely by air than by water, with a velocity from 20 to 100 miles an hour. It is only necessary to develop a suitable engine. Boulton-Watt's steam-engine might be a possible source of power, but as lightness is of so much value, there is the probability of using the expansion of the air by the sudden combustion of inflammable powders or fluids".

Thus Sir George Cayley had pointed the way to the petrol-motor, the gas turbine, and the jet-engine to power flying machines heavier than air.

The history of flight had begun with the brothers Montgolfier. Two more pairs of brothers were responsible for the final realization of Man's age-old dream of mechanical flight.

First came the Lilienthals, of Anklam, a small provincial town in Northern Germany. On a nearby moor, the two boys, Otto and Gustav, would lie for hours in the grass watching the hawks and buzzards and storks. They crept close to the birds to discover their secret: how did they lift themselves up in the air? Once they came so close to a stork that the bird opened its great wings in alarm, and flew up—*against* the wind!

Otto and Gustav were thoroughly excited by their discovery. This, they felt, must be one of the secrets of flight. At once they began to build wings and tried them out against the wind. They could not lift themselves up yet, but they felt such a strong pull that they knew they were on the right road.

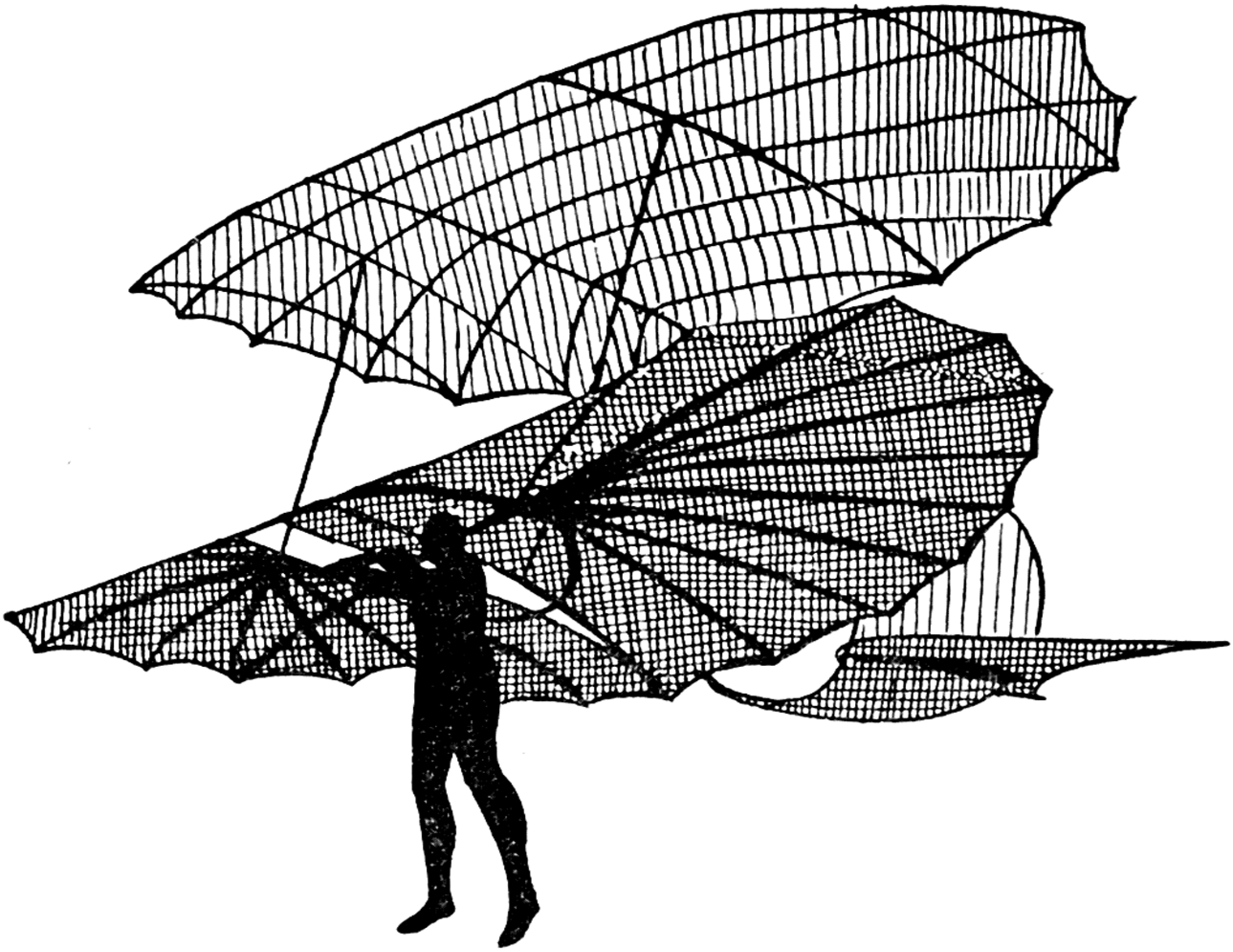
The Lilienthals were poor, and for many years there was hardly enough money to keep them and their widowed mother from starving. So they had to leave their experiments to a later date. When Otto Lilienthal was 43 years old in 1891 he could at last afford to buy a small piece of land near Berlin, containing a 50-foot hillock, and to build wing-like structures for gliding experiments.

Here Otto, assisted by Gustav, began with little jumps by allowing himself to be carried into the air from the hilltop by the rising current, and then land more or less gently at the foot. Later he ran up the hill against the wind, and was borne over the downward slope. Eventually he scored his first real success by gliding fifty feet through the air hanging from a large biplane of canvas and lath.

Once more on August 9, 1896, he set out on a gliding flight, with his brother Gustav timing him by a stopwatch. Suddenly, at a height of 50 feet, an unexpected gust caught his machine, blowing it to the ground. He died of a broken back. "Sacrifices have to be made," were his last words.

Somewhere in Ohio, another pair of brothers read the tragic news with more than a passing interest. Wilbur and

Orville Wright were the owners of a bicycle shop, but nothing fascinated them so much as the problem of flight. It was Otto Lilienthal's death which prompted them to devote all their money and all the time they could spare to the study of gliding.



Otto Lilienthal gliding in his biplane (1896)

Twelve Seconds over Kitty Hawk

"If God had wanted us to fly He would have given us wings," was then the prevailing popular prejudice, and the many victims of flying experiments seemed to point that lesson. The Wright brothers, however, were not only more systematic but also more cautious than their rivals. Instead of risking their own necks they built their first models in the form of kites, controlled from the ground by strings. The most formidable problem, they found, was that of balance: how to keep the machine steady in the air and prevent it from overturning.

One day when Wilbur was serving a customer in the shop his eyes fell on the flaps of a spare-part box, which his nervous fingers had twisted into different angles at opposite ends. This gave him the idea of designing wings that could be "warped" and adjusted during flight. In August, 1899, the first small-scale model of the "warping-wing" machine was ready for testing. The brothers went to a lonely place in North Carolina called Kitty Hawk, where wind conditions were favourable.

For over four years, Kitty Hawk was the scene of very slow progress and innumerable disappointments. One model after another was built, flown, and discarded. Summer after summer the Wrights returned with new machines, new ideas, new courage. Their first full-scale flying machine big enough to carry a man, and powered by an engine—which they had built themselves—was ready in the summer of 1903, and when they arrived at Kitty Hawk with it they knew that, before the season passed, either they would be the first people to fly by mechanical power, or they would give up for good.

There were so many difficulties and accidents, however, that it was December 14 before everything was ready for the great test. The villagers of Kitty Hawk had been invited to watch the first ever ascent of a flying machine; a few had come. The brothers tossed for the honour of piloting the machine; Wilbur called "heads" and climbed in.

The machine ran along the starting-rail, lifted, stalled, and came down with a crash, breaking a few parts. Wilbur was unhurt. The disappointed villagers were told to come back in three days' time for another attempt.

The wind was strong on that morning of December 17, 1903, but the Wrights decided: now or never. Only four men and a boy from the village had come to watch the event. Orville climbed into the machine. Wilbur started the propeller, and the holding-wire was released.

Ten years later Orville said that he still could not understand how he dared to make his first flight on an untried machine in a 27 m.p.h. wind: "After these years of experience, I look with amazement upon our audacity," he added.

After a 40-foot run along the rail the machine rose in the air, climbed to about ten feet, descended a little, went up again, and landed safely 120 feet from the point where it had lifted from the track. The flight had lasted 12 seconds: the first successful ascent of an engine-powered heavier-than-air machine.

The first aeroplane, flown by the
Wright Brothers at Kitty Hawk

Now it was Wilbur's turn to undertake the second flight. He covered about 200 feet in the air. The third ascent was again made by Orville; he flew a little farther, staying in the air for 15 seconds. On the fourth and last flight, Wilbur covered more than 850 feet in about a minute. But after the landing, when the half-dozen people present congratulated him, a gust of wind gripped the machine and damaged it. But now it did not matter so much: the great day was over, the history of the aeroplane had begun.

Wilbur survived his success for only nine years, but

Orville lived until 1948, watching during the span of his life the speed of aeroplanes grow from 30 m.p.h. (the speed at which he flew at Kitty Hawk) to the velocity of sound—twenty-five times as much. He died, 77 years of age, shortly after the sound barrier had been broken by machines so different from his first type that the word "aeroplane" hardly seems to apply to both. A new kind of aircraft, the jet 'plane, had come to stay: a revolution as great as that of December 17, 1903.

Jet-Engine and Gas Turbine

The name of Frank Whittle was familiar only to those fans of flying who used to watch the "aerobatics" at Hendon aerodrome in the years between the two world wars. They loved the thrill of the brilliant stunts to which Whittle treated them during the display. Little did they know that this young airman was working, over a period of eleven years, at the realization of an idea he had had as a boy apprentice in the R.A.F.

He was born at Leamington, and entered the R.A.F. Cadet Corps when he was 19. He went through the R.A.F. College, and it was there that he put his new ideas into an examination thesis in 1929, at the age of 22, on "Future Developments of Aircraft". In contrast to what his teachers had told the class about the probable trend of aircraft designing he wrote that in his opinion the propeller and the petrol-engine would one day become obsolete, to be replaced by jet propulsion!

But he did not stop at developing his theoretical ideas. He invented an entirely new engine for that form of propulsion—only on paper, of course—and took his plans to Government departments, experts on flying, and industrialists. No one saw in them anything but a young man's highly imaginative fancies. He took out a patent in 1930, but lacked the money to have it renewed. It looked as though he would have to shelve his invention for a long time.

Three of his friends, however, believed in him, and raked together enough money to build the first jet-engine. Only when the Second World War broke out did the Government show its interest in Whittle's invention, and the first jet-powered aeroplane was built in secrecy.

Then came the day of the first test flight: May 14, 1941. The machine, a Gloster, was taken up by Jerry Sayers, the famous test pilot who later lost his life in a crash. He flew the machine for 40 minutes; the real sensation was that everything went according to plan with this entirely new type of aircraft.

The jet-engine propels the aircraft by the force of expanding gases rushing out of a tube at the rear. But it also uses the principle of that other old motor, the turbine. Instead of causing individual explosions of gases in a cylinder, driving a piston up and down, as in the petrol and Diesel-engine, the fuel is burnt continuously, and the expanding gases press against the blades of a turbine, turning them round; then the gases rush out of the rear tube as a jet, acting upon the outside air as the explosion of a cartridge in a gun causes a recoil. The turbine is geared to a compressor which sucks in the air necessary for the combustion; the air intake is at the front of the aeroplane.

It is a much simpler machine than the petrol-engine; it can use cheaper fuel, it does not need any sparking plugs and ignition system, and, of course, needs no propellers. With this engine, an aircraft can achieve much higher speeds, and operate in much thinner air than a propeller-driven aircraft.

But the jet-engine also gave birth to another new motor, the gas-turbine. Instead of expanding gases being forced out from the jet they just drive the turbine, which in its turn operates wheels, ship's screws, or even the conventional propellers of an aircraft: the "turbo-prop" airliner has now established itself alongside the jet 'plane. It has already been adapted to drive railway engines, ships, and even motor-cars; in industry it will be one of the most efficient motors of the near future.

Another new type of aircraft which is likely to play an increasing part as a means of communication is the helicopter. This machine, too, was designed on paper and as a small model by Leonardo da Vinci around 1500, but only in recent years has it come into existence thanks to the efforts of a number of inventors in various countries, chiefly those of Igor Sikorsky, a Russian aircraft engineer who settled in America. Sikorsky helicopters are now operating in America and Europe for many purposes. They can "do anything a horse can do", as Sikorsky once said; and considerably more than ordinary aeroplanes: they do not need landing strips or airports, but can take off and land from a square, a roof, or a backyard; they can fly forwards, sideways, and even backwards, or hover in the air like insects.

Helicopters have no fixed wings but a large horizontal rotor above the cabin, which lifts the aircraft up and controls the direction of its flight by the angle at which the blades attack the air. It has another, vertical little propeller at the tail which helps to steer the machine and keeps it from spinning round with the rotor.

It is a slow and leisurely aircraft; but just because of that it may bring more pleasure to the flying traveller than the supersonic stratosphere cruiser which leaves its passengers little time to enjoy Man's brilliant achievement—the conquest of the air.

Chapter Eight

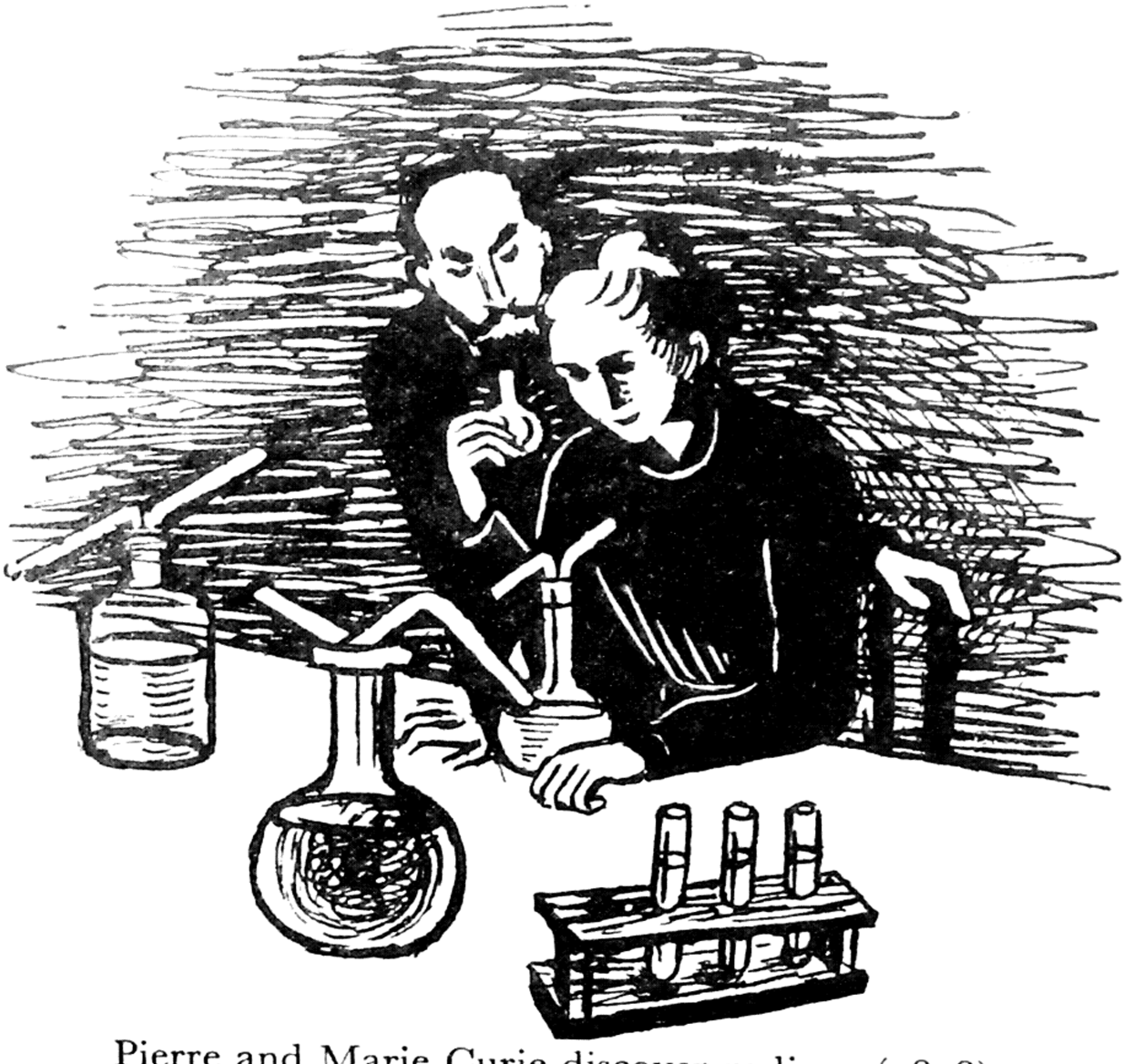
SECRETS OF THE ATOM

THE word "atom" is really a misnomer. For nearly two and a half thousand years, men believed that all matter consisted of very small particles which could not be divided. The philosopher who formulated that theory around 500 B.C., Democritus, called these particles atoms, from the Greek word *atomos*, indivisible. Each element, it was found, had its own kind of atom, and until about two generations ago it was thought impossible that one kind of atom, one element, could be changed into another kind. The mediæval alchemists who believed that lead or some other base metal could, by some magic, be turned into gold were regarded as fools or charlatans.

But one night in November, 1898, the whole edifice of that time-honoured atomic theory crumbled to dust.

The Shining Element

Marie Sklodowska was the gifted daughter of a professor in Warsaw, who sent her to Paris to complete her studies. Her teacher, Professor Becquerel, made her his assistant. For many years, Becquerel had kept a few pieces of uranium from Bohemia in an unused drawer. One day, Marie Sklodowska took some of them out and used them to weight photographic plates; but when the plates were developed they showed a strange network of veins as though glowworms had run across them. There could be no doubt—the uranium was giving off a yet unknown kind of rays. No one realized that this radiation was a phenomenon that might perhaps upset the whole foundation of natural science.



Pierre and Marie Curie discover radium (1898)

No one—except Marie Sklodowska. Or rather Marie Curie, for she had married a young physicist, Pierre Curie.

Determined to discover the mysterious source of those rays, she gave up her post as Professor Becquerel's assistant. One night she examined a geological map of Europe with her husband. Where could large uranium deposits be found? Their searching fingers stopped at a little dot indicating Joachimsthal in Bohemia. They looked it up in reference books: a little country town which had been Europe's greatest silver mine in the Middle Ages. But now the silver mines were exhausted, and there was only some dye-stuff production for which the uranium pitch-blende was suitable.

The Curies lost no time in writing a letter to the management asking if they could have, free of charge, 10,000 kilograms of the pitch-blende.

Their request was granted. The manager was sure these scientists in Paris were mad, but there was so much of the stuff lying about—his men usually shovelled it into the river—that it was quite a relief to get rid of some of it. It was packed into empty soda barrels and dispatched to Nogent-sur-Marne, where the Curies had been given the use of a chemical factory for their experiments by Baron de Rothschild.

In order to find that hidden element in the uranium pitch-blende, the mass had to be boiled down. For weeks and months, Pierre and Marie did the strenuous work of stirring it with heavy poles in enormous buckets; what remained was first filled into pots, then into rows of glass bowls. The end of the process found them with only a small test-tube containing a little whitish liquid.

One night in November, 1898, the alarm clock rang in the shed near the laboratory to wake Pierre and Marie, who had taken a short nap on a shake-down.

"Wake up, Pierre. It's three o'clock. It will have crystallized by now." The crowning moment of their tremendous labours was near: out of ten thousand kilograms of uranium pitch-blende, the first few grains of a new element had been won. What, they wondered, would it look like . . . *their* element?

They opened the door to the laboratory—and stopped on the threshold. From the corner of the dark room came a distinct, bluish, mysterious light. It was a fantastic and almost frightening sight. Marie pressed Pierre's hand.

Then they lit the gaslamp. At once the bluish light vanished. But where it had glowed stood a little test-tube holding one-tenth of a gramme of an off-white salt.

They named it "radium"—the Shining Element.

The Skeleton Hand

The discovery of radium meant, as Madame Curie had foreseen, the complete upsetting of many scientific beliefs. Physicists and chemists suddenly felt the ground give way under their feet. What was matter? What was energy? they had to ask themselves anew. So the atom was neither unchangeable nor was it the smallest existing particle; for radium owes its existence not only to a natural transmutation of elements extending over millions of years, but it disintegrates itself—within the space of 1,600 years, half of any given quantity of radium changes from matter to radiation, that is to energy. As Marie and Pierre Curie studied the way in which this disintegration occurred, they laid the foundation of the modern theory of the atom. . . .

A few years before the Curies' discovery, one autumn afternoon when dusk began to fall, Professor Wilhelm Konrad Röntgen was experimenting in his laboratory at the University of Würzburg in Bavaria. On the table lay a cathode-ray tube, which had been the subject of his studies for some time. It had been invented by an Englishman, Sir William Crooke: a glass bulb from which the air had been pumped, fitted with two metal plates at either end, called the cathode and the anode; the cathode was connected with the negative and the anode with the positive pole of a battery—and electricity passed through the airless space of the bulb. The cathode began to glow when the current was switched on, giving off some kind of rays which were then being investigated by a number of physicists, Professor Röntgen among them. For want of a better name they were called cathode-rays.

Professor Röntgen tried out his tube under various conditions. On that afternoon, for instance, he had imprisoned it in a cardboard box. Suddenly his eye fell on a sheet of paper with some fluorescent coating, which was lying on his workbench near the box, left there from some previous experiment. It had lit up, emitting a greenish glow into the dusky room. Strange! thought Professor Röntgen; where there's fluorescence there must be a source of light. But where was it? The box with the cathode-ray tube was shut tightly. Yet when he switched off the current the fluorescent paper became dark again!

It must be that these cathode-rays were a kind of "invisible light", he thought. And where there's light there must be a shadow. He held his hand in front of the paper to see if it would cast a shadow—then suddenly snatched it back again.

Was it hallucination? He thought that, for the flash of a moment, he had seen a skeleton hand on the fluorescent paper, the eerie shadow of his own hand: the bones appearing in black outlines, the flesh and skin forming a thin, greyish fringe.

His amazement turned into a feeling of immense triumph. By accident he had discovered an uncanny new kind of rays—invisible rays which could penetrate solid objects; with the density of the shadow depending on that of the material which the rays struck on their path. Thus, flesh was more transparent to them than bones, wood more than metal. They would enable man to see the inside of things, living and dead; they would reveal what had hitherto been hidden by Nature.

Röntgen called them X-rays because of their mysterious nature. When the cathode-rays struck some material object, such as the cardboard of the box, they turned into X-rays. Many years later, the English scientist, J. J. Thomson, at the Cavendish Laboratory, Cambridge, found out what those cathode-rays really were: they consisted of negative particles of electricity. He called them "electrons".

It took the scientists many years to get a clearer picture of what was happening inside the cathode-ray tube and the disintegrating radium atom. The jig-saw puzzle of the atomic world grew into shape. The atom began to be thought of as some kind of miniature solar system with a "sun", the nucleus, and some "planets", the electrons, revolving around it. The nucleus is very densely filled with matter, like a crowd of people on a dance floor: there are protons, particles with positive electric charges, neutrons, particles without an electric charge, and perhaps some mesons, with a positive or negative charge, acting as a kind of "glue" which holds the nucleus together. The electrons, which have next to no mass or weight, are negatively charged. Normally, there are as many positive protons as negative electrons in an atom so that their charges cancel each other out—we call such an atom "neutral". If, however, there are fewer electrons than protons, the atom becomes positively charged; if there are more electrons, it is negatively charged.

Atomic Energy—Controlled and Uncontrolled

Now, what makes the difference between the various elements is the number of electrons revolving around the nucleus, and the corresponding number of protons within the nucleus. Hydrogen, for instance, being the lightest element, has only one of each; uranium, the heaviest, has 92. So the mediæval alchemists who believed that there must be a way of changing one element into another were not completely wrong: if you want to change lead into gold all you have to do is to knock three electrons and protons off the lead atom, which has 82 of each—and there is your gold atom with only 79! The knocking-off process, however, would be much more expensive than the gold you would get.

An atom with an electric charge, that is with fewer or more electrons than protons, is called an ion. Its electric balance is disturbed. Thus the ion plays an important part in many electric phenomena.

Radio-activity—the process which makes the "unstable" element radium disintegrate—was the first indication of the fact that matter and energy are not as different from one another as scientists had believed for many hundreds of years. Radium shoots out particles, in the form of rays, at high speeds; the energy which powers the particles comes from the destruction of a small bit of the atom itself. It was Professor Albert Einstein who showed in his *Theory of Relativity*, published in 1905, that there is no real difference between mass and energy, and that the destruction of matter would liberate enormous energies.

To-day we know that if one ounce of matter could be completely destroyed and changed into energy it would yield as much power as we derive from burning 100,000 tons of coal in a power station. But in 1905, when Einstein came to his mass = energy conclusion on the strength of the new discoveries of the 1890s, the whole idea was so fantastic that many scientists attacked Einstein's theory violently; there seemed then no possibility of proving it in practice by splitting the atom and releasing that miraculous energy.

The connection between X-rays and radium became apparent when it was found that Röntgen's new rays were not only able to let the doctor see inside his patient's body, but also to destroy unsound cells and dangerous growths such as tumours and cancer—and that radium, by its constant ray bombardment, could do the same thing.

In the radium atom, Nature has lifted the catch which holds the particles of matter together like a coiled spring, and the pent-up energy is freed in the form of rays—partly minute bits of matter, partly electro-magnetic waves.

In 1932, Lord Rutherford, Professor of Experimental Physics at the Cavendish Laboratory, Cambridge, succeeded for the first time in splitting an atom artificially. He made particles from radium rays collide with nuclei of lithium atoms. The nuclei broke up under the impact of these sub-atomic "bullets"; protons from the split nuclei rushed away at tremendous speed, while the remaining nuclear wrecks became atoms of another element—helium. The transformation of elements had been achieved, nearly as the alchemists dreamt it. What happened was that each of the lithium nuclei, which have three protons, lost one proton by the impact of the radium particles—and the atom with two protons is that of helium: it was as "simple" as that.

In a dozen countries, physicists repeated Rutherford's experiments, discovered new facts about "nuclear fission", and suggested new ways of achieving the transformation of matter into energy. Then the second World War broke out, and behind the curtain of official secrecy began a race for the most terrible weapon in human history—the atom bomb, a bomb in which that nuclear fission could be produced so that tremendous destructive forces would be let loose.

On Monday, August 6, 1945, cheerful crowds in England enjoyed the first Bank Holiday after the end of the war in Europe. On that day an American aeroplane dropped one bomb on the Japanese town of Hiroshima. That bomb was more powerful than 20,000 tons of highexplosive—the first atom bomb. A few days later, a second bomb was exploded over Nagasaki. Japan surrendered; the second World War had come to an end. Those two bombs had caused terrible destruction and loss of life.

The atom bomb consisted of two masses of Uranium 235—that is, an "isotope" of the "ordinary" uranium, which has the atomic weight of 238. An isotope is a special variety of an element, differing from it only in the number of neutrons in its nucleus. Uranium 235, which is contained in very small quantities in Uranium 238, is much more "unstable", that is, it disintegrates much more easily, and when it reaches a certain quantity the whole mass of it can undergo a sudden "chain reaction": every neutron hitting a nucleus liberates three neutrons; these hit other nuclei, and within the fraction of a second the whole mass of uranium disintegrates, changing into tremendous energy in the form of heat. This process is called uncontrolled chain reaction; it is set off in the atom bomb by bringing the two masses of U235 together so that the "critical quantity" is reached.

There is yet another, much more powerful nuclear weapon—the hydrogen bomb. It is a man-made "sun" in which hydrogen is turned into helium, releasing energy in the form of terrific heat. In the hydrogen bomb, an "ordinary" atom bomb is used as a fuse to set off that chain reaction.

Chain reaction can, however, be controlled. But this is a very complicated process. It is the process by which we shall make atomic energy the most powerful servant mankind has ever known.

The Atomic Pile

The question has often been asked why scientists were able to make atom bombs so much earlier than atomic piles, or nuclear reactors, as the machines for the production of atomic energy are called. There are three reasons for this: the difficulty of producing sufficient quantities of Uranium 235 from the world's limited supplies (and of persuading the military authorities to let the engineers and scientists have some of it for peaceful purposes); the difficulty of getting rid of the dangerous by-products of an atomic pile; and the difficulty of designing chain reactors which would be safe to operate.

The third problem was by far the most formidable; for there is always the risk of an uncontrolled chain reaction—an explosion. It is mainly a question of using a reliable "moderator" to control the chain reaction in this atomic furnace, which creates tremendous heat as a result of the bombardment of the uranium atoms by neutrons. The moderator—such as graphite (carbon), some gas (for instance, carbon dioxide), or "heavy water" (water with an isotope of hydrogen)—acts as a brake on the nuclear fission and cools the pile at the same time. The heat created by the pile is used to drive a conventional steam turbine geared to an electric generator, as described at the end of Chapter Two. In the atomic pile, the uranium atom "splits" when bombarded by a neutron; as a result, it releases two or more neutrons, which go on to split other uranium atoms. This chain reaction is slowed down by the moderator, which swallows up so many neutrons that an explosion is averted. It all depends, therefore, on the efficiency of the moderator.

The necessity of getting rid of the dangerous by-products makes it advisable to build atomic piles "self-contained" so that no radio-active material reaches the outside world. This is rather difficult and explains why it has taken such a long time to design atomic power stations, for even the water used for driving the steam turbines will be radio-active after passing through the pile, and would "contaminate" the whole area if allowed to run, say, into a river when it has left the turbines. It must first be rendered harmless; and the whole pile must be heavily shielded so that no radio-activity may injure people outside it. For the engineers working in such a power station, very strict safeguards are necessary. All these problems had to be solved before the construction of an electricity-producing nuclear reactor could begin.

The ease with which other materials are "contaminated", that is made radio-active, has, however, one great advantage: such an atomic pile can create more "fuel" than it uses! In a "breeder" reactor, as this type of pile is called, an artificial element such as plutonium—an uranium isotope with two more protons and electrons (94) than uranium—can be produced by constant neutron bombardment. This radio-active element can, in its turn, be used to start a new atomic pile. When, in 1947, Britain's first atomic pile was set up at Harwell, Berkshire, it was at once used to "cook" a number of ordinary chemicals—that is, to make them radio-active for medical treatment of diseases and for biological and industrial research. These new radio-active chemicals can be used like radium itself, or for the purpose of tracing normally invisible processes—be it the path of some medicine inside the human body, or the course of some beetle in the soil.

So the discovery of radium has led us to the gates of a new world, to the beginning of the Atomic Age. It is up to us all to decide whether the power of the atom is to be used to destroy civilization—or to create a Golden Age of peace and plenty for mankind.

Chapter Nine

WORLD OF ELECTRONICS

One day in November, 1887, the German physicist Heinrich Hertz, aged thirty, carried out an experiment which opened the door to a vast new realm—that of wireless communication.

Hertz was a quiet, unpretentious scientist with a short and uneventful career. He had chosen as his special field the study of electrical phenomena. There were two opposing theories about electricity: one said that electricity was due to the activity of very small, charged particles of matter; the other, that it was, like light, a wave motion. Hertz wanted to show that these two theories were not really opposed to each other, and that electro-magnetic waves could quite well be combined with the movement of very small particles.

His decisive experiment was simple and ingenious. In one corner of his laboratory at the Polytechnic in Karlsruhe he set up an electric induction machine; in the other he put what he called a "resonator": a wire ring broken by two small metal balls with a gap of a fraction of an inch between them. The inductor had unusually large metal plates, which increased the "frequency" of the electromagnetic waves produced by the machine—the number of oscillations per second. Between these two machines was nothing but air.

Hertz set the induction machine in motion, and to his great satisfaction he saw that he was right, for the gap between the metal balls at the other end of the laboratory was bridged by a number of tiny sparks! Hertz had thus proved that there were indeed electro-magnetic waves, spreading in all directions from an oscillator, which could be picked up and made visible.

For the first time, electro-magnetic waves had been consciously produced and picked up; in fact, Hertz had invented and built the first wireless transmitter and receiver. But being a scientist he did not attempt to do something "practical" with his instruments. For the next seven years he went on with his fundamental work on these waves, whose existence he had proved. He showed that they could be reflected and refracted just like visible light, that they moved in empty space with the speed of light, and that the scientists who believed that electricity and light were essentially the same thing were right—that both phenomena are electro-magnetic waves which differ from each other only in their wavelengths.

Guglielmo Rings a Bell

In December, 1894, a twenty-year-old student by the name of Guglielmo Marconi achieved his first great success with experiments which he had been carrying on for many months in an attic of the spacious Villa Griffone near Bologna, where his well-to-do parents lived. One night he woke his mother, who had already gone to bed, and asked her to come up to his laboratory where he wanted to show her something important.

Signora Marconi grumbled, but she went with her son. In the attic, he told her to watch an electric bell which he had fitted on a table in the midst of some mysterious apparatus. Then he went to the opposite corner of the room, and pressed a Morse key.

Sparks crackled, and twelve feet away the bell rang.

Signora Marconi tried to show as much enthusiasm as her drowsiness would permit, but she was not sure if the ringing of an electric bell was really a good reason for disturbing her night's rest. Only later did she realize that she had watched the first transmission of a signal by wireless.

Guglielmo Marconi's next step was to build a telegraphic receiver for wireless signals. With the help of Alfonso, his younger brother, he extended the range of his signals across the garden of the villa; the transmitter was in the house, and the receiver set up on the far side of a little hill. Alfonso was posted at the receiver, and when the signals duly arrived he climbed up the hill and did a Red Indian dance to tell Guglielmo that the thing was really working.

A few months later Guglielmo Marconi sailed for England, which was bound to feel the greatest interest in his experiments. Mr. (later Sir William) Preece, chief engineer in the telegraph department of the General Post Office, had been trying to find some new means of communication with the lightships all around the British coast, and he was eager to test the young Italian's invention.

The Atlantic Bridged

The world's first wireless telegraph station was installed in May, 1897, at Lavernock Point, near Cardiff, where Marconi set up a 100-ft. aerial mast; three miles away, in the Bristol Channel, the receiver was set up on the small island of Flat Holme in a shed near the lighthouse. On the first day not a single signal was heard in the earphones with which Marconi and Preece hoped to receive the dots and dashes from the transmitter. Marconi, quite unperturbed, suggested that a higher aerial be set up at the receiver. This was done, and on the second day the first, faint signal clicked in the earphones: three dots and one dash, the Morse letter "V".

Marconi turned and smiled at the engineers. "*Ecco*," he said, "there you are!"—as though this was the most ordinary thing in the world.

Within twenty-four hours, he was the hero of the day all over Europe: another age-old dream of mankind, that of instantaneous communication across space, had come true; and there was no doubt that within a short time wireless telegraphy would bring about revolutionary changes, especially at sea. For the first time, there was a possibility of sending messages to and from ships!

Experimenting day and night, Marconi succeeded with surprising speed in increasing the distances covered by his apparatus. A week after the first test he sent signals over nine miles. In the summer of 1898, the Prince of Wales fell ill on board his yacht off the Isle of Wight while Queen Victoria was staying at Osborne House on the island. Marconi offered to set up wireless communication between these two points so that the Queen could be kept informed about her son's progress. For 16 days, this communication was maintained without break or hitch, and 150 telegrams were sent in both directions.

In March, 1899, human lives were saved for the first time by wireless telegraphy. A few British ships having already been equipped with Marconi transmitters, one of them, a patrol boat, chanced to see a steamer stranded on the Goodwin Sands, and told the Foreland lighthouse by wireless. So immediate help was forthcoming and lives saved. A few months later, British naval manœuvres were carried out with wireless transmission of orders over a distance of 75 miles, and Press telegrams were exchanged between England and France.

Within less than three years, Marconi had increased the range of the transmitter fifty-fold by constant experimenting. Yet the greatest step was still to come.

On December 12, 1901, Marconi and a few of his assistants squatted in an ancient wooden hut near St. John's, Newfoundland. It was icily cold; there was no heating, the wind blew through the cracks in the walls, and the rain seeped through holes in the roof. There was no food except some cocoa and a bottle of whisky. But what did it matter? There was a vital problem to be solved that day, and a most important question to be answered. It was this: did the electro-magnetic waves, as some physicists believed, shoot out straight into space, or did they follow the earth's curvature?

If the path of the waves was straight they would leave the earth, and there was no hope of connecting continents by wireless. Marconi himself was doubtful. But everything depended on this day: between noon and 3 p.m., East American time, his transmitter at Poldhu, Cornwall, was to send out the signal "S", three dots, with all its transmitting power.

At noon, Marconi put on the earphones—and there it was, unmistakably: tick-tick-tick . . . tick-tick-tick . . . the three dots from Poldhu! The waves had crossed the Atlantic.

Music on the Air

At the early age of 35, Marconi received the Nobel Prize for physics. But he had to pay the penalty for his fame. Many people envied and hated him because of his success. They accused him of trying to establish a world monopoly so that every ship and shore station would have to be equipped by the Marconi Company—which was not true, for there were already numerous companies making wireless equipment in other countries. In the midst of what was called the "Marconi scandal" came the news of the

Titanic disaster. The giant liner had struck an iceberg on her maiden voyage in April, 1912; 1,500 people lost their lives, but 700 were saved thanks to the wireless operator, who directed other ships to the scene of the accident by his SOS calls. At the New York inquiry into the sinking of the *Titanic*, Marconi was present, and the part played by wireless telegraphy in the drama of the sinking liner was stressed by all witnesses.

A year later, the first arrests were made with the help of the new means of communication. A couple suspected of murder succeeded in getting on board a ship bound for Canada from Liverpool, but the Captain had his suspicions about them and wirelessed Scotland Yard. A detective took a faster boat, and when the two stepped on land in Canada, handcuffs were already waiting for them.

In 1915, Marconi began systematic experiments with wireless telephony—radio—and early in 1920 he invited his friends to a party on board his yacht, *Elettra*, at which they danced to music transmitted from London. Shortly afterwards, he was able to transmit a telephone conversation from Lisbon to the *Elettra*, cruising 300 miles out in the Atlantic. A few months later, on December 21, 1920, the first regular broadcasting station began its service, the station "8ZZ" in Pittsburgh, Pa., operated by the Western Electric and financed by commercial advertising.

The reason why broadcasting had to wait for more than twenty years after the beginning of wireless telegraphy was the same which delayed the coming of the telephone after the introduction of telegraphy. It is much easier to open and close a simple electric circuit according to the Morse signals to be transmitted, than to transform the complicated and delicate modulations of speech or music into electric impulses. Bell discovered that this modulation needs a steady, uninterrupted current, modulated by a magnet according to the impulses coming from the microphone. The technicians had to wait for the invention of the thermionic valve, by the English physicist Sir Ambrose Fleming, before they could develop a practical system of wireless telephony.

Fleming's valve was a simple vacuum tube with a length of wire that could be heated electrically until it glowed, emitting a stream of electrons. Small changes of voltage in the current with which the valve was supplied showed themselves as variations in the electron stream. The American inventor, Lee de Forest, put a wire mesh screen, or grid, in the path of the electrons so as to control the flow of electricity through the valve.

This, then, was the vital tool for the production of modulations in the transmitter, for picking them up in the receiver, and also for amplifying the weak impulses arriving "over the air" as electro-magnetic waves. The radio transmitter sends out a continuous "carrier wave" of a constant frequency; this is modulated by the electrical impulses coming from the microphone. The receiver is "tuned" to the carrier wave, and the received impulses are amplified and fed into a loudspeaker. But the thermionic valves, in one form and another, can be adapted to serve many more purposes. As they emit electrons, the entire field of application for these valves—radio was only the beginning—is called electronics.

England was the first European country to introduce broadcasting. On February 14, 1922, the Marconi Company opened its experimental station near Chelmsford, and in November of the same year, the "British Broadcasting Corporation"—the B.B.C.—began its regular daily programme from London. One of the greatest revolutions in the lives of the people in our time had begun.

Guglielmo Marconi lived long enough to watch this tremendous change which he had done so much to bring about. And when he died in 1937, another development, no less important, had already begun—the development of television.

The Magic Mirror

Paul Nipkow, a sixth-form boy in the small West Prussian town of Neustadt, was fascinated when, in the late 1870s, his science teacher told the class what he knew about that new technical miracle, the telephone. Paul and his friend Fritz decided to build such an instrument themselves. But how? Their schoolboy cheek helped them. Somehow they succeeded in getting the loan of Neustadt's single, precious telephone from the Post Office—for one night!

Of course they did not sleep a wink that night. They took the telephone to pieces, copied every part of it (with a microphone made of little nails as they had no carbon granules), and put it together again. In the morning the telephone was returned to the Post Office in perfect working order, and the boys had their own instrument. They installed their telephone line from Paul's to Fritz's house. It really worked. One day, Paul said to his friend, "You know, Fritz, it wouldn't be bad if we could not only *talk* to each other by electricity, but also *see* each other at the same time!"

From that moment, the idea obsessed Paul Nipkow. He went to Berlin to continue his studies at the University, pondering all the time how to make what he called an "electric telescope"—how to extend the range of the human eye by electricity. It was the idea of the magic mirror from the fairy tales: the wicked queen in the story of Snow-white, for instance, had one. . . .

The problem, as he saw it, was that of transforming light into electric impulses. One day he read about the element, selenium, discovered by the Swedish scientist, Berzelius, in 1817. A cable engineer by the name of May noticed in

1873 that some selenium bars which were used as resistances at the transatlantic cable station in Valencia Harbour, Ireland, let the current pass much more freely when the sun was shining on them than at night. This, thought Nipkow, pointed the way to the solution of his problem. On Christmas Eve, 1883, he was sitting under the Christmas tree when an idea occurred to him quite simply—the basic idea of television: how a scene could be transmitted electrically.

The "Nipkow Disc", as that invention came to be called, was an ordinary cardboard or metal disc, with a series of small holes arranged in the form of a spiral near the edge of the disc. Nipkow visualized quite clearly how it was to be used to transmit pictures: a kind of camera would be set up in front of the scene or object to be transmitted, with the disc in it, turned by a motor. A strong lamp shoots a beam of light through the holes of the rotating disc at the object; thus it is scanned, that is, dissolved into many brighter or dimmer spots. The spiral arrangement of the holes makes sure that with one revolution of the disc the whole scene is scanned.

The scanner runs the moving spot of light over the scene as the eye scans a printed page, line by line, when we are reading. The brighter or dimmer reflections from the light spots are picked up by a selenium cell, which is connected to a battery at one end and to the receiver at the other. According to the varying intensity of light the resistance of the selenium varies, and these stronger or weaker impulses travel to the receiver, where they make a lamp flicker. There is another disc with spiral holes in the receiver, running exactly like the one in the transmitter; and the flickering light is thrown through the disc holes on to a screen, where the original picture is built up again from its individual spots.

Paul Nipkow's "electrical telescope" of 1883—which he had patented in Germany—contained the basic element of television: the principle that the scene to be transmitted must be dissolved into innumerable "units" of light intensity, that these units must be transmitted (by wire or wireless) and reassembled in the receiver. But as there were enormous technical difficulties confronting him, Nipkow eventually abandoned his invention and joined the railway service.

Razor Blade or Television?

John Logie Baird was born at Helensburgh, near Glasgow, in 1888, the youngest son of a clergyman. His health was so delicate that he was unable to attend the local school regularly.

His mechanical bent exhibited itself early. As a small boy he built his own telephone line; but when a storm tore down the wires, which somehow or other pulled a coachman from his seat, Mr. Baird had to intervene and calm the furious man, and John was in consequence forbidden to dabble further in electrical science. Nevertheless he was not to be restrained and subsequently built a little hydro-electric generator, which supplied the current for lighting the house by means of a miniature turbine operated by a nearby brook.

Until the beginning of the first World War he studied physics and electricity at the University of Glasgow, and then, failing the medical examination when volunteering for the army, he took the job of superintendent engineer at the Clyde Valley power station.

But one day a friend sent him a travel agency's folder advertising the perpetual sunshine of Trinidad, and he decided to go to the island and set up an import business. The business proved unsuccessful; so, taking a forlorn chance, he started a small jam factory in a village where he was the only European. But again bad luck pursued him: he contracted malaria, and his doctor advised him to return to England. He did so, and went to Hastings to recuperate.

From there he wrote to his sister in Scotland, asking for her advice: which of two pet ideas of his should he take up—a new type of razor blade or television?

The razor blade, of course, replied his sister. But his destiny was not to be denied, and despite the well-meant advice he took up television.

There is no parallel, in the whole of modern technical history, to the circumstances under which John Logie Baird attacked one of the most difficult of all inventions. He was without money and his health was extremely poor. Furthermore, for many years he had had no contact whatsoever with scientific or technical development. So the task which he undertook in his primitive garret at No. 8, Queen's Arcade, Hastings, in 1922, must have seemed completely hopeless. But to-day that house proudly exhibits a plaque bearing witness to the fact that television was indeed invented then and there by John Logie Baird.

His wash-stand became the fundament of the whole apparatus. It was joined by an old tea-chest to house the electro-motor, which he bought from a jumble heap behind an electrician's shop. The motor was to turn the Nipkow disc—the only part of the apparatus which had been invented by someone else—cut out of a piece of cardboard. An empty biscuit tin became the container of the projection lamp, with lenses which cost 4d. each bought from a local bicycle shop. Then there was a disabled wireless telegraph from an army store, some torch batteries, darning needles, and scrap timber—all held together by glue, sealing wax, and lengths of string. Around and across the whole makeshift laboratory there was a maze of electric wire.

With the tireless patience of the true inventor, Baird worked for many months amidst this technical hotchpotch. And then at last, in the spring of 1924, he succeeded in transmitting the flickering shadow of a Maltese cross by wire over a distance of three yards.

Now he needed money for further work, and when he got it at last he moved to London and set up his apparatus in a top-floor room at No. 22, Frith Street, in Soho—a house which also bears a plaque commemorating Baird's achievement.

One day in 1925, Mr. Gordon Selfridge, of the well-known London department store, engaged him at £25 a week, plus free provision of all necessary material, for "personal appearances" three times a day in the store's radio department, where he was to demonstrate his invention and answer customers' questions.

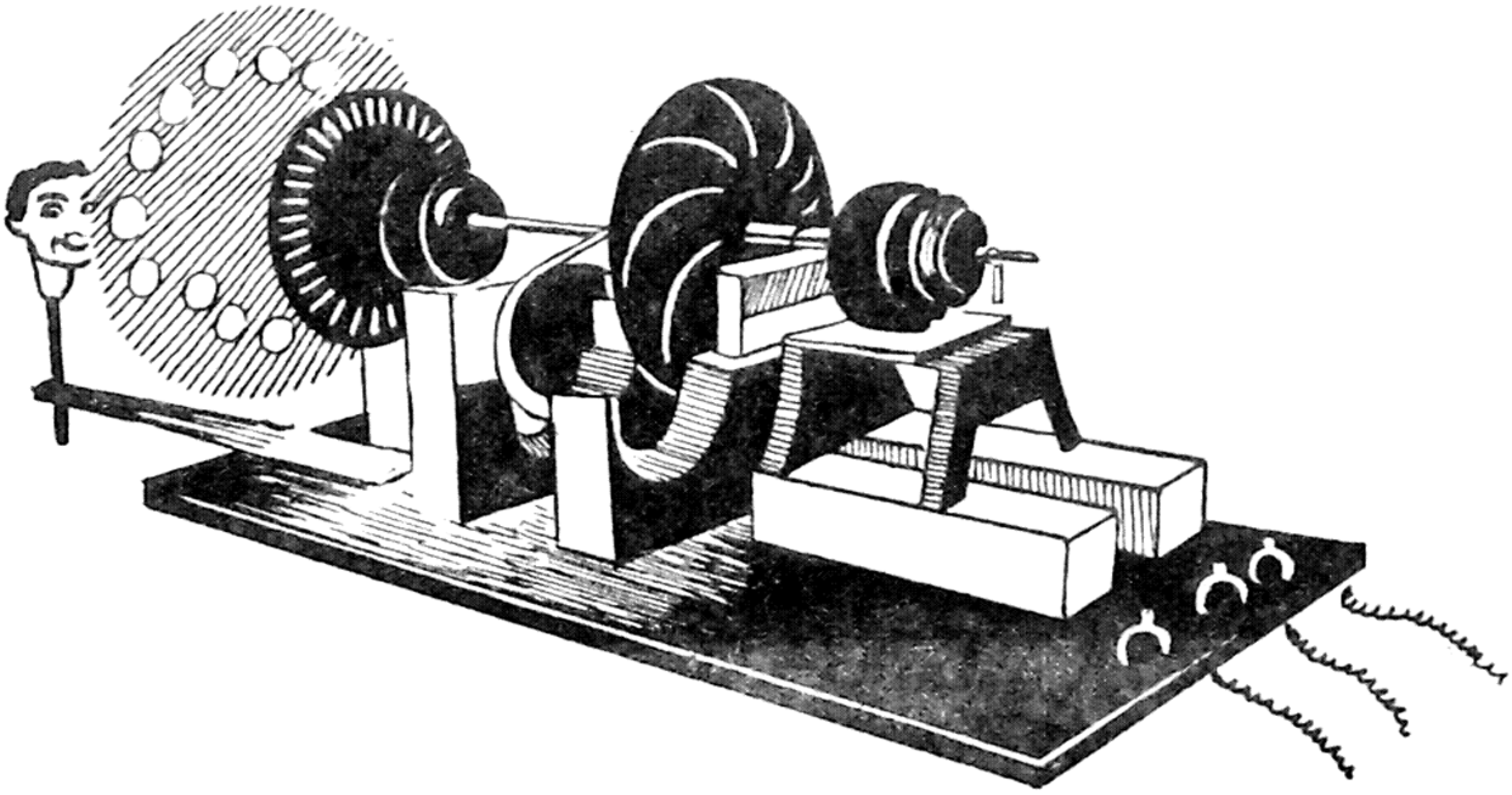
But urgently as Baird needed the money, after a few days he found himself unable to endure being on exhibition and the target for endless questioning. Besides, the invention was still too imperfect for all the publicity; he had not yet succeeded in transmitting the features of a human face.

A Living Bill to Televise

As a first step to this end he began experiments with an old ventriloquist's doll named Bill in front of the transmitter. And one day—on October 2, 1925—he had the supreme satisfaction of seeing Bill's head acquire features on the screen: a greyish shadow grew into a detailed face! Now Baird had only one thought—to get a living "Bill" before his transmitter. He rushed down the stairs to the office of a firm below his room, and grabbing the first person he found—the office-boy, William Taynton—he dragged him upstairs. And so, too frightened to resist the "mad inventor fellow", Bill the boy took the place of Bill the doll. He was the first human being to be televised;

Baird himself was the second, for Bill was allowed to peep into the receiver while the inventor pulled faces before the transmitter in order to give the boy an extra treat.

How had Baird achieved his success? The two outstanding features of his system were these: First, the point-by-point scanning of the scene in the transmitter with the help of a Nipkow disc and a photo-electric cell. In the receiver, a beam of light passed rapidly over the screen, varying in intensity according to the impulses coming from the transmitter. The whole procedure took place at great speed.



"An old ventriloquist's doll gazing at this technical miracle": Baird's original television transmitter

Second, the synchronization of the transmitter and receiver by means of a special signal which was transmitted at the end of each of the 30 lines from which the whole picture was built up on the screen.

During the following years, Baird perfected his system, improving the "definition" of his pictures so as to show more details, and increasing the range of wireless transmission. Naturally, he expected the B.B.C. to start experimental transmissions with his system; but this proved to be a false hope. Influential circles were against Baird and against the whole idea of television. Baird decided to fight; and by mobilizing the friends he had among the Members of Parliament he succeeded in getting the support of a Parliamentary Committee. The B.B.C. was more or less forced to start regular experiments in September, 1929, from the Crystal Palace.

The Electron Gun

For some years the Baird Television Company enjoyed a monopoly; but then began the challenge of rival systems. Thousands of research workers in hundreds of well-equipped laboratories all over the world tried to find a better system than the one Baird, single-handed, had devised in his lonely attic. The resources of America's biggest electrical companies were put at the disposal of the scientists and technicians. It would have been surprising if Baird had not been beaten by that vast army of inventors. Besides, he made the vital mistake of sticking to his system of "mechanical scanning" by means of the Nipkow disc instead of switching over to electronic scanning, which alone was able to achieve a higher "definition", that is, a picture with greater detail.

Hungarian-born Dr. V. K. Zworykin, of the Radio Corporation of America, entered the race with his electronic system. His TV camera is almost a replica of the human eye: a lens, representing the cornea, casts an image of the scene to be transmitted upon a plate at the wide end of a cathode-ray tube; this plate, an imitation of the human retina, is covered with tiny photo-sensitive nodules, very close together but each insulated from its neighbours. When the image picked up by the camera lens falls on this "mosaic", the nodules become electrically charged to a greater or lesser degree according to the amount of light which falls on them, so that the mosaic represents a faithful electrical "picture" of the scene to be televised.

At this mosaic, an "electron gun", which is essentially a cathode-ray tube, shoots a thin beam of electrons, which scans the whole picture line by line many times per second. As the beam passes over each nodule the charge that has accumulated in it is carried away by the electron stream (electrons, we know, are particles of negative electricity): it is like the action of a weightless brush. The charges from the nodules are thus picked up one by one, and are used to modulate the transmitter wave—which carries the make-up of light and shade in the picture in the form of varying impulses to the receiving set.

The essential part of the receiver is a large cathode-ray tube with a zinc-sulphide coating on the inside of its wide end, which forms the "screen". Here, the incoming impulses steer an electron beam moving fast across the screen, line by line, thus building up the picture. Synchronization is achieved, as in Baird's early system, by transmitting a special signal after each line. The whole picture is scanned, transmitted, and reassembled 25 times per second.

On November 2, 1936, the world's first high-definition television service began to operate from London's Alexandra Palace. The two rival systems, Baird's and Zworykin's, were at first used on alternate weeks. But as Baird could not achieve a better definition than 240 lines while the Zworykin system had 405, the outcome was that in February, 1937, the Baird system was abandoned and that of Zworykin adopted for good.

During the second World War, Britain's TV service closed down; it was reopened in June, 1946, and from that time dates a rapid improvement and development in TV technique thanks to the efforts of British and American inventors. Cameras have been designed which can televise an object quite clearly by the light of a single candle. "Zoom" lenses can bring, within a second, an object from a distant view to a close-up. Portable microwave links enable the camera to "go places", and to send back to the transmitter pictures from any outdoor event (for instance, a boat race as seen from an accompanying launch on the water).

John Logie Baird had soon got over the disappointment of the B.B.C.'s decision to use the American system, and began to experiment with transmissions in colour and depth—developments which, as he foresaw, would one day be wanted by TV viewers.

But he died in 1946 in the midst of that work, only 58 years old. Life had, after all, been too strenuous for the man who had invented television and worked so hard to make it everybody's entertainment.

From Thunderstorms to Radar

There was a particular problem which seemed of great importance to the young meteorologist, Robert Watson-Watt, the son of a Scottish carpenter, who had entered the Royal Air Force Establishment at Farnborough shortly after the first World War. That problem was how to warn airmen of thunderstorms. Civil aviation was developing by leaps and bounds, and many flying accidents happened because pilots were unable to avoid running into thunderstorms.

Watson-Watt believed that wireless telegraphy could show a way to deal with this problem. He began to study those crackling noises called atmospherics, which were such a nuisance to the wireless operator. Thunderstorms are electric phenomena, he reasoned, so a great deal of that crackling must come from them.

He worked out a great research programme on atmospherics, to be carried out by a whole army of volunteers. The B.B.C. had just come into existence, and he had the brilliant idea of asking radio enthusiasts in many countries for their help. They were given in advance the texts of B.B.C. talks which were to be broadcast at a certain time on a certain day; they were to mark those syllables in the script which were accompanied by atmospheric crackling.

Reports duly came in from all over Europe and North Africa—from Bergen to Madeira, and from Potsdam to Cairo. They proved that thunderstorms could be received by radio, and their directions determined, up to distances of 4,500 miles.

In 1927, at the age of 35, Watson-Watt was put in charge of the Radio Research Station at Slough, near London, and from there he undertook extensive trips to various parts of the world to "make atmospherics sign the visitors' book", as he once put it. Some years later he became Superintendent of the Radio-physical Station at Britain's great National Physical Laboratory in Teddington, and it was there that he received, one day in December, 1934, a secret inquiry from a Government department asking him what he thought of the so-called "death rays" of which the Press and some scientists had been talking—was there really a possibility of inventing such rays that would kill or paralyse people at a distance, set off explosives, or bring cars and tanks and 'planes to a stop?

He replied with a long report which explained to the Government department that death rays were bunkum; but that he had another, more practical idea which had occurred to him during his work on atmospherics: a system by which aeroplanes could be discovered through cloud, fog, and darkness. He called it "radiolocation".

The Government was mildly interested, and he was granted a small sum of money to go ahead with his research. He collected a team of young radio technicians and began.

Radar—as this system was called later—was born early in 1935 in a field ten miles from the powerful B.B.C. transmitter of Daventry, where Watson-Watt set up his equipment. The very first tests were successful: aircraft flying in the transmitter beam reflected the wireless waves quite strongly. Watson-Watt's theory proved correct: that a wireless "echo" from the aircraft could be received accurately on the ground, and its distance, direction, and speed determined. "The wings of an aeroplane are like a kind of horizontal wire in the air," Watson-Watt explained. "When you aim a powerful wireless beam at them they turn into a 'secondary transmitter' and send the waves back at the angle of incidence, just as a mirror reflects light rays."

The next problem was how to keep the whole research work secret; for the great value of this new invention would depend on the fact that an aggressor should have no idea that he was being "seen" even in a cloud and at night. So the radiolocation team set up headquarters in a remote part of the Suffolk coast near Orford.

Radar in War and Peace

There Britain's "secret weapon" took shape rapidly. Already in December, 1935, five radar stations were working experimentally. By March, 1936, aircraft could be spotted up to distances of 75 miles. From Easter, 1939, there was an uninterrupted, invisible radar "wall" from Aberdeen to the Isle of Wight—a chain of stations manned day and night.

Then came the war, and radar proved its tremendous value in the Battle of Britain, enabling "the Few"—the fighter pilots—to stave off the enemy's massed assault and then it helped to beat the night bombers in the "blitz".

Yet the general public knew nothing about the invention; and when Watson-Watt became Sir Robert in 1942, the Press was still not allowed to disclose why he had been knighted. With the turning tide of the war, radar developed rapidly into a whole number of devices to assist offensive operations in the air and at sea. Only after the end of the war, the full story of radar and of Sir Robert's achievement was told.

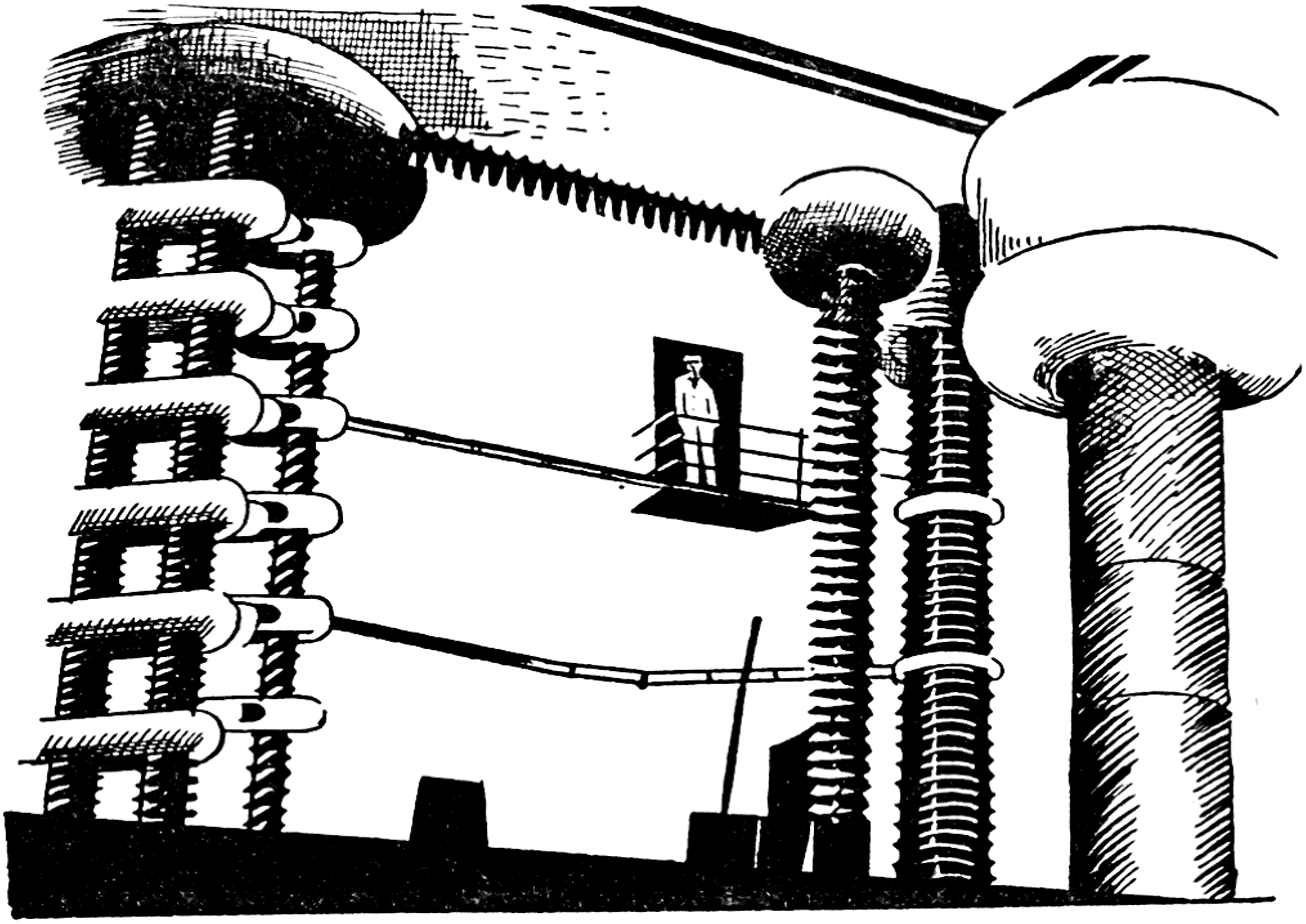
To-day, radar has found innumerable peace-time applications. Most big ships are equipped with it; harbours have been made safe with its help, civil aviation works with it to avoid thunderstorms and collisions in the air, and to bring aircraft safely down to the runway in fog and at night; it discovers icebergs and helps with whaling, guides Congo steamers through sandstorms and ferries across the fog-bound Thames.

How does the modern radar equipment work?

High up above the ship's bridge or the control tower of the airport rotates the "scanner", the radar aerial, which looks like a disc cut in half. Most scanners are "double-deckers": the upper section is for transmission, the lower for reception. The scanner rotates at a speed of 10 to 25 revolutions per minute; usually, the transmitter and receiver are built in and rotate with it.

The transmitter sends out about 1,000 bursts of V.H.F. (very high frequency) waves of about 3-centimetre length every second; they are concentrated in a narrow beam. An important part of the apparatus is the "modulator": it provides a very short "pulse" so that the transmitter sends out its bursts of waves for exactly 0.1 millionth of a second each, and for that time only; during that period, the receiver is disconnected from the aerial. The transmitter valve is the so-called magnetron, a small valve capable of sending out these very short pulses on very short wavelengths; it starts and stops sharply.

As soon as one burst has gone out, the receiver is connected to the aerial and "listens" for the echo to come back. The returning echo from an object in the path of the wave beam is picked up by the lower part of the scanner, amplified, and fed to the "magic eye" of radar—called "P.P.I.", Plan Position Indicator, in technical language. For the operator, this is the screen of his equipment.



High tension room at the Cavendish laboratory, Cambridge

It is the wide end of a cathode-ray tube, just like the screen of a television set. Around the neck of the tube are two coils which act on the beam of electrons inside, just as optical lenses act on a light beam. The "Focus Coil" determines the sharpness of the picture on the screen, and the "Deflection Coil" produces a revolving trace of bright "blobs" on the screen. This coil rotates in step with the scanner.

The trace is actually a series of echoes picked up by the aerial, and "painted" on to the screen by the beam of electrons. As soon as an echo is received from some object in the path of the pulse, a stream of electrons is released from the cathode; this brightens the fluorescent screen at the exact distance from the centre of the tube so that the range of the object can be read from the scale on the P.P.I. This corresponds to the time taken for the radar pulse to travel to the object and return to the scanner. The bright "blob" remains on the fluorescent screen for a few seconds, and brightens again with the next revolution so that the operator can see the direction and speed of movement of the object, or of his own ship in relation to it.

Thus radar paints a faithful picture of the scene which the naked eye may not be able to see. It works reliably by day and night, through cloud and fog.

The Electronic Brain

Electronics has, in hundreds of applications, transformed life to a great extent during the last twenty or thirty years. It is the keyword to broadcasting, television, and radar, to gramophone recording and the sound film. The miniature radio telephone, nicknamed "Walkie-Talkie" when it was first used by the Allied armies in North Africa in 1942, has found many peacetime uses: in the mines, in traffic control, in desert and high altitude expeditions. In wire telephony, the so-called co-axial system for long-distance connections enables 660 simultaneous conversations to be carried on over a pair of metal tubes, each 0.375 ins. in diameter; each conversation needs a small radio transmitter and receiver tuned to a special wavelength.

In factories and laboratories, radio waves are already being used to rivet, weld, and case-harden metals, to glue and dry plywood, and for soldering and brazing processes. Electronic devices can control the production of sheet iron, plastic fibres, bread, and a hundred other things; and engineers are already talking about the "push-button factory" in which every process, from the intake of the raw material to the final check, will be controlled electronically and automatically.

Already in 1932, a team of scientists built the first electron microscope in Berlin. It is an instrument fundamentally different from the "old-fashioned" light microscope, which cannot magnify objects more than about 2,000 times. The electrons, whose characteristics are different from those of the light rays, can do better. Their velocity is only about 62,000 miles per second, or one-third of the velocity of light. They can only travel in a vacuum, and air is to them as opaque as ink is to light rays; neither can they penetrate glass. But they can magnify objects 50 times as much as a light miscroscope!

In the electron microscope, a beam of electrons is used to illuminate the object. The "lenses" are wire coils—the electrostatic and magnetic fields created by the coils serve as condenser, objective, and eyepiece or projector. Thus the electron beam emanating from a heated filament can be made to enlarge the image of a small object, such as a microbe, on a thin celluloid sheet. The electrons hitting the hard parts of the microbe are stopped, but the rest go through until they arrive at a fluorescent screen, where they are made visible like a TV picture, or at a photographic plate where they can be recorded.

"Seeing is believing"—but it is not always recognizing. So far, scientists have been able to identify only some of the minute objects they have seen with the help of the electron microscope. But once they have found their way through the strange new world which this instrument has unlocked for them, research by this new means will be of enormous benefit to mankind.

Perhaps the most fascinating application of electronics is what scientists call "cybernetics"—in popular language: the "electronic brain". The grandmother of this new race of machines was "Bessie", built in 1944 at Harvard University—a long, slender, glass-covered collection of 760,000 components including several thousand cathode-ray valves, ingeniously wired and assembled so as to be able to answer innumerable mathematical questions about rocket motors, astronomy, nuclear physics, aerodynamics, or trigonometry. The longest job Bessie has ever carried out took her 103 hours; it was a certain mathematical problem relating to uranium fission. A human mathematician would have needed one hundred years!

To-day, Bessie has many children and grandchildren. They are called "automatic computers" or "homeostats", and scientists do not favour the term "brains". For although these machines can do a great deal of "thinking", they must first be told *what* to think about and *how* to do it. But given these instructions they can work miracles. They can do equations with 50 or 100 unknowns within seconds, and a 20-figure multiplication in one ten-thousandth of a second. They do not solve mathematical problems the way we would do; the job is so arranged for them that each valve or relay has only two alternatives of reaction: "pulse" or "no pulse". The trick is that the machines are not fed with decimal numbers, but with figures in "binary" form, that is, as a sequence of powers of 2. Binary numbers are like ordinary numbers except that every digit is either a one ("pulse") or a nought ("no pulse").

These machines have "memories" like a human brain: they can store numbers and instructions; and they have the ability of choosing which instructions to obey next, according to the result of the work so far completed. It is this latter quality which makes the machines adaptable to a very great number of operations which make up the solutions of large problems; and it is this feature which the physiologists are studying in order to discover more about the working of the human brain.

Will these robots one day become independent and begin to "out-think" their maker, Man? That danger does not exist, even if we arm them with sensitive organs such as photo-electric cells, pressure gauges, microphones and so on, and with tools to carry out all kinds of jobs. They can, it is true, relieve us of much toil and sweat. But Edison has once said that genius is one per cent. inspiration and 99 per cent. perspiration. That one per cent., that divine spark which has enabled Man to create the world in which we live, will never kindle the flame of genius in a machine.

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